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COLD LAKE - BEAVER RIVER WATER MANAGEMENT STUDY

VOLUME 2
WATER SUPPLY

Appendix A . . . Surface Water Resources
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Water Resources

Alberta
ENVIRONMENT
Planning Division

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COLD LAKE — BEAVER RIVER
WATER MANAGEMENT STUDY

VOLUME 2
WATER SUPPLY

PREPARED BY
PLANNING DIVISION
ALBERTA ENVIRONMENT
December 1983

Submitted to: Hon. F. Bradley
Minister of Environment

APPENDIX A

SURFACE WATER RESOURCES

A Report Prepared By
NORTHWEST HYDRAULIC CONSULTANTS LTD.

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Our File Number AE-COLD(2)/673

June 18, 1982

Mr. Ron Hicks, P.Eng.
Alberta Environment, Planning
9th Floor, Oxbridge Place
9820 - 106 Street
EDMONTON, AB
T5K 2J6

Dear Sir:

Re: Second Draft - Beaver River Cold Lake Report

We are pleased to submit our final report, updated to include the latest model run of April 27, 1982. You will note that the principle conclusions of the report are that additional hydrometric data will be required to confirm the study results and that the flow estimates can be readily updated as additional data become available.

We thank you for the opportunity to have carried out a most challenging assignment and trust that the report assists your branch in assessing the water resource development opportunities in the Beaver River Cold Lake basin.

Yours truly

NORTHWEST HYDRAULIC CONSULTANTS LTD.

L.E. Bodnaruk, P.Eng.

LEB/smd

Encl.

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SUMMARY

A surface water supply study was undertaken to estimate streamflows and lake water levels at 27 points in the Beaver River and Cold Lake basins, as a continuous time series over the period 1956 - 1980.

The required data were estimated from;

- existing hydrometric data where available;
- correlation of hydrometric data to extend the available record for several short-term stations;
- a computer model analysis for study points that had little or no hydrometric data.

In addition, a brief survey was conducted to gather data on the outlets of several lakes.

Results of the analysis compared well with the limited data available on water levels and discharges within the basin. Historic effects of beaver damming activities were shown to be significant at many sites.

CREDITS AND ACKNOWLEDGEMENTS

Thanks are expressed to Mr. Ron Hicks, P.Eng. of Alberta Environment, Planning Branch, for nis direction of the project and to Mr. Ron Bothe, P.Eng., Alberta Environment, Hydrology Branch, for his assistance in data assembly and for his technical reviews which have helped to ensure the quality of the results.

This study was conducted by staff of Northwest Hydraulic Consultants Ltd. under the direction of Mr. L.E. Bodnaruk, P.Eng. Mr. G.V. Gehmlich and Mr. S. Madsen were responsible for computer model applications and Mr. B. Berry was responsible for computer model design. The field survey was led by Mr. S. Seidel. Technical reviews were provided by Mr. C.R. Neill and Mr. E.K. Yaremko.

1. INTRODUCTION

Alberta Environment has undertaken a study of water resources in the Beaver River and Cold Lake basins of eastern Alberta. The purpose of the regional study is to develop a framework plan for the long-term management of the surface and groundwater resources in the region likely to be affected by development of the Cold Lake oil sands.

The regional water resources study includes as one component the analysis of surface water supply. The Surface Water Supply Study was commissioned to Northwest Hydraulic Consultants Ltd. and has as its general objectives the analysis of natural streamflows within the study basin and the synthesis of a 25-year record of streamflows and water levels at a number of selected locations. Specifically, the terms of reference of the Surface Water Supply Study were as follows:

(a) Select study points where streamflows will be required in the analysis of water quantity demands (i.e. at existing or potential withdrawal points for industrial users, at potential regulated lakes, etc.) and in the analysis of water quality demands (i.e. at existing or potential waste discharge points).

(b) Review available streamflow, lake level, precipitation and evaporation data; screen and select suitable data.

(c) Convert streamflow data to natural flow data where necessary.

(d) Extend natural flows at gauged points to the specified period 1956-80.

(e) Determine natural flows at ungauged selected study points as per (c).

(f) Determine the accuracy of the extended and estimated natural flows calculated at each of the selected study points.

(g) Using long term station data for adjacent and hydrologically similar watersheds, determine the frequency of occurrence of dry and wet periods within the period 1956-80.

(h) Prepare a report outlining the work program and results, and detailing all data, methodologies, and assumptions used to derive the study results.

A further objective of the study was to develop a methodology that could be readily refined in future years as additional streamflow data became available within the watershed. Since it was recognized that only a first estimate of the required hydrological data would be initially possible with the existing date base, it was important that the methodology could be easily updated in the future.

The methodology that was developed to meet these objectives involved the synthetic generation of sub-catchment flow estimates and the routing of these flow estimates through a computer model of the river system to compute flows and water levels at the required sites.

The principal results of the study are the computer routing model and a data file containing flow data at the selected study points. The model and the data file has been provided to Alberta Environment separately from the present report and includes the following:

- all model data;
- tables and plots of stream discharges and lake elevations;
- summary statistics of discharges and lake elevations;
- streamflow data for input into the water balance model (by Nanuk Engineering and Development Ltd.) for the assessment of water management alternatives.

This report is intended to complete the requirements of the study, specifically to fulfill objective (h) above; to detail all methodologies and assumptions used to derive the study results, and objective (f); to discuss the accuracy and limitations of the derived flows.

2. STUDY AREA

2.1 Physical Features of the Study Area

A general view of the study area is shown in Figure 1. The study area includes the drainage basins of the Beaver and Cold Rivers in the east-central region of Alberta. It has an area of 22,000 km^2, of which 15,500 km^2 lies within the Beaver River basin and 6,500 km^2 within the Cold River basin.

The Beaver River has its headwaters in Beaver Lake near Lac La Biche and a length of some 150 km to the Alberta-Saskatchewan border. Its major tributary is the Sand River which drains about one-third of the basin but contributes one-half of the total Beaver River flow. Other smaller tributaries (from west to east in the basin) are the Mooselake River, Manatokan Creek, Jackfish Creek, Marie Creek, Muriel Creek, Reita Creek, and Redspring Creek.

The distribution of drainage area within the Beaver River watershed is approximately as follows:

Tributary	Drainage Area (km^2)	% of Total
Beaver R. above Sand R.	5260	33%
Sand River	5040	34%
Mooselake River	900	5.9%
Manatokan Creek	410	2.7%
Jackfish Creek	490	3.2%
Marie Creek	730	4.7%
Muriel Creek	790	5.2%
Reita Creek	270	1.7%
Redspring Creek	520	3.4%
other	920	6.0%

Within the Cold River basin the primary water features are Primrose and Cold Lakes and the Martineau River connecting the two. Primrose Lake is the largest lake in the study area (445 km^2) and Cold Lake is second largest (350 km^2). This basin includes the watershed of the Medley River as shown in Figure 2.

Primrose Lake drains just over one-half of the Cold River basin within the study area and the Medley River drains about seven percent.

The Cold River is the outlet from Cold Lake. It eventually joins the Beaver River some distance further downstream in Saskatchewan.

A schematic plan showing the more significant elements in the watershed is shown in Figure 3.

Several major physiographic regions are apparent in Figures 2 and 3 as follows:

- the Beaver River basin upstream of the Sand River confluence (local areas 101 and 102) and the adjacent watersheds of Punk, Seibert, and Spencer Creeks (local area 108). This region consists of irregular, poorly drained topography; much of it, especially in the west, is dotted with numerous small lakes which would be expected to reduce runoff from the area by evaporation from the lake surface. Further downstream this area has more intensive agricultural use. Ground elevations in this part of the watershed vary from about 580 to 640 metres above sea level;

- the northern portion of the watershed, in the headwaters of the Sand, Wolf, and Medley Rivers,

Marie Creek, and Primrose and Cold Lake. This area is characterized by extensive areas of treed muskeg with moderate relief. It includes local areas 104, 105, 107, 118 119, 120, 131, 132 and 133 and extends as far south as the upper headwaters of Manatokan and Jackfish Creeks. Much of this area is uninhabited and lies within the Air Weapons Range rising to an elevation of about 760 m;

- the central portion of the watershed along the main stem of the Beaver River. This area has little relief and low runoff and is largely developed for agricultural purposes. It generally lies at an elevation of 550 to 580 metres above sea level. It includes several local areas tributary to the Beaver River (local areas 115, 122, 130, and 134) and the downstream portions of the watersheds of the smaller tributaries;

- the southern part of the watershed, within the upper watersheds of Mooselake River, Muriel Creek, and Reita Creek. This area is noteable for large areas of lake relative to the drainage area. Larger lakes in this area are Moose Lake, Muriel Lake, Charlotte Lake, Reita Lake, and Angling Lake. Higher elevations, in the range of 580 to 760 m above sea level, occur in this part of the basin.

These differences in physiography have significant implications for watershed runoff as will be discussed later.

2.2 Climate

The following is a brief overview of the climate of the Cold Lake area, abstracted from Reference 1.

The climate of the Cold Lake area is typically continental, featuring large annual, seasonal, day-to-day, and diurnal temperature variations along with a summer precipitation maximum. The summer precipitation maximum is due mainly to convective activity associated with modified maritime polar air, the most frequent summer air mass.

The average annual precipitation is 470 mm; annual variations are from a maximum of 630 mm in 1960 to a minimum of 310 mm in 1967. The greatest monthly precipitation occurs in July, with an average of 90 mm. July also holds the record for the most precipitation in one month: a total of 179 mm in 1971. The greatest one-day rainfall (94 mm) occurred in July 1962.

Thunderstorms occur from April to October, although only a few occurrences have been reported in the months of April or October. Thunderstorm activity reaches a maximum in July, occurring on an average once in 7.7 days.

Seasonal snowfall, based on the months September to May, averages 135 cm[1]. This has varied from a maximum of 236 cm to a minimum of 70 cm.

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1 The water equivalent of 1 cm of snow is approximately 1 mm.

The first measurable snowfall usually occurs in early October; the first measurable snowfall that lasts throughout the winter usually occurs in mid-November and remains until early April. December has the highest monthly snowfall, with an average of 26 cm.

Large annual variations in temperature illustrate the continental type of climate of Cold Lake. The mean monthly temperature varies from -19.1°C in January to 17.2°C in July; the mean annual temperature is 1.2°C. The record maximum temperature of 36.1°C occurred in July 1964 and the record minimum temperature of -48.3°C was recorded in January 1954.

2.3 Runoff Characteristics

The general pattern of runoff in the study area is illustrated in Figure 4 which shows the recorded discharge hydrograph for the Beaver River near Cold Lake over the period 1956 - 1980. Typically, the annual peak occurs from snowmelt in the second half of April and is often followed by several smaller rainfall peaks. However, the highest flow on record in the basin occurred in June 1962 as the result of rainfall runoff. The second highest peak flow resulted from snowmelt in April 1974.

The year of lowest runoff was 1968, and the year of highest runoff was 1962.

Mean annual runoff estimates for various parts of the study basin are presented in Table 1. Data for Table 1 were abstracted from a number of sources and were based on flow records of various levels of quality and extent,

so that they should be considered as estimates only. All values have been adjusted, as best as possible, to a common time base. In this table surface runoff is defined as runoff from land surfaces (not including the major lakes in the watershed). Net runoff is the remainder calculated when direct precipitation on lakes is added to surface runoff and evaporation from the lakes is subtracted.

For purposes of comparison, Table 1 also contains data for three basins outside the study area:

- Dillon River at outlet of Dillon Lake, immediately northeast of the Cold Lake basin.

- Beaver River Dorintosh local, which is the inflow between the Beaver River gauge at Cold Lake (526) and a gauge located further downstream in Saskatchewan, east of the study area.

- Atimoswe Creek, located to the south of the study area.

Comparison of runoff estimates in Table 1 reveals a wide variation within the basin. There is a general trend of decreasing runoff from north to south; the greatest annual surface runoff (125 mm) occurs within the Primrose-Cold Lake basin, followed by the upper Sand River watershed (94-104 mm), the upper Marie Creek watershed (70 mm), Jackfish Creek (54 mm), and finally the lower Beaver River (48 mm). This trend is confirmed by the data for the Dillon River (138 mm) to the northeast, higher than any area within the study basin, and Atimoswe Creek (26 mm) to the south, lower than any area within the study basin.

These variations in annual runoff largely parallel the differences in physiography discussed above.

There are no data on which to base the estimation of runoff in the southern part of the basin, other than a limited amount of flow records on Columbine Creek, located in the south-central region. These data indicate an annual runoff of about 45 mm for Columbine Creek, roughly equal to the mean runoff in the lower Beaver River watershed.

2.4 Study Points

Twenty-seven study points were selected by Alberta Environment and are shown in Figures 1, 2 and 3. These study points are as follows.

Location	SSARR Model Designation
Main stem	
Amisk River near Highway 36	102
Beaver River at Goodridge	502
Beaver River above Sand River	503
Beaver River above Jackfish Creek	515
Beaver River above Marie Creek	5171
Beaver River at Beaver Crossing	526
Sand River	
Caribou Lake	204
Sand River above Wolf River	505
Wolf Lake	506
Sand River at Truman	508

<u>Mooselake River</u>	
Moose Lake	210
<u>Manatokan Creek</u>	
Manatokan Lake	212
<u>Jackfish Creek</u>	
Tucker Lake	216
Jackfish Creek at mouth	516
<u>Marie Creek</u>	
Burnt Lake	218
May Lake	219
Marie Lake	220
Ethel Lake	221
Marie Creek at mouth	521
<u>Muriel Creek</u>	
Muriel Lake	223
Muriel Creek at mouth	525
<u>Reita Creek</u>	
Reita Lake	227
Angling Lake	228
Reita Creek at mouth	529
<u>Cold River</u>	
Medley River	132
Primrose Lake	231
Cold Lake	233

3. HYDROMETRIC AND METEOROLOGICAL DATA BASE

An index map of hydrometric and meteorological stations in the study area was provided by Alberta Environment and is reproduced in Figure 5. This map shows the location and period of record for streamflow gauges operated by Water Survey of Canada, streamflow and lake elevation gauges operated by Alberta Environment, and several additional streamflow and lake level gauges operated by Esso Resources Canada Ltd.

The period of record for hydrometric stations is shown in Figure 6. As shown in this figure, there are only two hydrometric stations in the study area that have records for the entire 1956 to 1980 period: the Beaver River at Cold Lake Reserve (discharges) and Cold Lake (elevations). All other stations have records that are either short term, seasonal, or discontinuous.

Forty short-term intermittent stations shown in Figure 5 that do not coincide with designated study points are not included in Figure 6.

The hydrometric stations have been grouped into three categories depending on the length and continuity of record. These categories are:

- <u>first order stations</u>. Stations of this type have continuous records for the whole study period and are the Water Survey of Canada (WSC) gauges on Cold Lake and on the Beaver River at Cold Lake Reserve. Cold Lake levels were recorded on a weekly or bi-weekly basis, but are considered continuous because they do not change greatly in

that short a time by virtue of the large amount of lake storage.

- second order stations. These are stations that have a significant length of continuous or seasonal records, and include the WSC Sand, Wolf, Amisk, Beaver, Goodridge, and Jackfish streamflow gauges. These stations all have approximatey 10 years of record that is continuous during the summer season. Only the Wolf gauge has winter season records.

- third order stations. These stations have short term, intermittent, or occasional records and are primarily the lake level stations operated by Alberta Environment and short-term stations operated by Stanley Associates Engineering Ltd. for Esso Resources Canada. Data for third-order stations are too sparse to be of direct use in determining lake levels or discharges for the 25-year period; because they are so sparse, their usefulness in the present study is primarily as a means of verifying the computed results.

The locations of the first, second and third-order stations relative to the watershed schematic are shown in Figure 7.

A large number of meteorological stations are indexed on Figure 5, but only a small number lie within the study area. Most of these stations report air temperature and precipitation, and several report other meteorological parameters such as wind, sunshine and pan evaporation.

Meteorological data are not used in this study other than in estimating lake evaporation, and consequently the data will be given little discussion. Evaporation estimates based on the Cold Lake airport data were used in this study as will be discussed later.

4. STUDY METHODOLOGY

A brief introduction to the study methodology is given below. Further details are provided in subsequent sub-sections.

As noted above, the basic study objective was to calculate weekly streamflows for 27 selected study sites for the period 1956 to 1980.

Of the 27 sites, two have streamflow or lake level records for the whole study period, Beaver River at Cold Lake (Beaver Crossing) and Cold Lake. These correspond to the two first-order hydrometric stations. Daily flows have been recorded on the Beaver River since late 1955 and weekly or bi-weekly lake elevations have been recorded on Cold Lake since 1954.

Of the remaining 25 sites, 5 are located at second-order streamflow sites that have roughly ten years of data; the Amisk River at Highway 36 (study point 102), Beaver River near Goodridge (502), Sand River (508), Wolf River (506), and Jackfish Creek (516). All have seasonal record only (spring to fall) except the Wolf River site which has a continuous record. For these sites, the available record was extended to 25 years by correlation with the Beaver River streamflow gauge at Cold Lake Reserve. This analysis will be discussed in some detail later, and involves the following steps:

1. interpolation between late fall and early spring for stations that have no winter record,

2. correlation of recorded daily streamflow with the Beaver River at Cold Lake Reserve,

and 3. calculation of streamflows for the earlier period using the regression equations developed in the correlation analysis.

At the remaining 20 sites, hydrometric data are at best sketchy and at worst non-existent. Discharges and lake levels therefore had to be determined by other means.

A computer modelling approach was adopted for the 20 remaining sites. The basis of this approach is a computer model to simulate the streamflow runoff and routing process within the basin. It involves essentially two tasks: calculation of local runoff hydrographs into lakes and streams, and analysis of routing and water balance to calculate stream discharges and lake water levels at the specified points.

A daily time step was adopted for the calculations instead of the weekly time step proposed in the terms of reference. This decision was made because:

- restrictions in the computer model allow a maximum length of time step of about four days;

- the input data for the correlation analysis and for the model are recorded on a daily basis and thus would have to be converted if a longer time step were adopted;

- the output data would be directly compatible with time steps of seven days or longer and could be converted if necessary at that stage.

Thus the selection of a daily time step was primarily for computational reasons. This should not be

taken to suggest that the results are necessarily meaningful on a daily basis.

The computer model will be discussed in some detail in a later section.

To provide additional data required in the routing analysis, a brief survey program was also conducted.

5. CORRELATION AND EXTENSION OF STREAMFLOW DATA

The objective of the correlation or regression analysis was to extend the data record of the second-order stations to a common 25-year time base, by correlation of the five second-order station flows with those of the Beaver River at Cold Lake.

The first step in this analysis involved the estimation of winter base flows for the four seasonal gauges (Sand River, Amisk River, Beaver River at Goodridge, and Jackfish Creek.) Winter base flows for the four stations were estimated by exponential interpolation using an equation of the form;

$$Q = Q_o \, e^{-k(t-to)}$$

where Q = computed discharge on day t

Q_o = measured discharge on day t_o

and k = recession coefficient

Values of k were computed directly from the last fall flow measured in each year (typically in early November) and the first flow measured at the start of the subsequent year (typically late February or early March). Values of k for each winter for each station were computed by solving the above equation using the two recorded flows. The computed values of k were then substituted along with the recorded Q_o to calculate daily discharges.

Where the computed k for a given winter deviated markedly from the norm for a station, it was assumed that the recorded early-winter flows were being affected by unusually high fall runoff. In these cases, daily discharges were calculated with the above equation using a

"normal" or average value of k and the recorded late-winter flow, and the recorded fall flows were extrapolated to meet the recession line. These adjusted winters are as follows:

Sand River	1970/71
Amisk River	1973/74
Jackfish Creek	1973/74

Approximately 40 equations were used (4 stations X 10 years), each of the general form above and differing only in the value of the coefficient k.

The second step in this analysis was a regression made with a standard linear regression program. Linear regression is a general statistical technique through which one can analyse the relationship between a dependent or criterion variable and an independent or predictor variable. This relationship is expressed as a predictive equation of the form;

$$Y = a + bX$$

where Y is the dependent variable (for example the daily discharge on the Sand River),

X is the independent variable (the daily discharge for the Beaver River at Cold Lake in the present analysis),

and a and b are coefficients that are calculated by a least-squares curve-fitting technique in the regression analysis.

In the present study, a regression analysis was made of daily flows at each of the 5 second-order gauge sites with the daily flows on the Beaver River at Cold Lake

(study site 526). All recorded flows at the second-order sites were used in the analysis. In addition, estimated winter flows were used for the four seasonal gauges.

To account for lagging or delay between stations, the independent and dependent data were lagged by periods of up to several days and the lag that gave best results was adopted. This provision allows for delays in the river system due to lake routing and stream travel time.

The resulting regression equations express the relationship between daily flows at the desired location with daily flows in the Beaver River at Cold Lake. Adopted regression equations (in Imperial units of cfs) and the correlation coefficients are given below:

Equation	Correlation Coefficient
$Q_{Sand} = 0.4944\ Q_{Beaver}$	0.952
$Q_{Wolf} = 0.05779\ Q_{Beaver_{(t-5)}}$	0.936
$Q_{Amisk} = -12.0 + 0.1705\ Q_{Beaver}$	0.923
$Q_{Goodridge} = -21.6 + 0.3005\ Q_{Beaver_{(t+2)}}$	0.915
$Q_{Jackfish} = 0.02844\ Q_{Beaver}$	0.922

In the above equations, the subscript (t-5) denotes a value measured on the Beaver at Cold Lake 5 days earlier and (t+2) denoted a value measured at Cold Lake 2 days later than the date for which a discharge is being computed.

There are two simple statistical measures of the strength of the relationship between the two variables and thus of the accuracy of the results, the Pearson product-moment correlation coefficient (or simply correlation coefficient) and the index of determination.

The correlation coefficient can have a value between 0.0 and 1.0; a value of 0.0 indicates that no relationship exists and a value of 1.0 indicates perfect agreement. The index of determination is calculated as the square of the correlation coefficient and is a measure of the proportion of variance in one variable explained by the other.

In the present analysis the correlation coefficients range from 0.92 to 0.95 and the index of determination ranges from 0.84 to 0.91; i.e. some 84% to 91% of the variation in the dependent variable is explained by the regression equation. These are relatively high values and indicate a fairly strong relationship between gauges.

A visual assessment of the strength of the relationship and hence the accuracy of the regression equation is given by scatter plots and comparative hydrographs, Figures 8 to 12 and 13 to 17 respectively. These figures show that the regression equations provide a good general agreement with recorded flows, although individual flow values may be substantially in error. These errors result primarily from two factors:

1. the variability of rainfall and snowmelt within the watershed; ie. no rainfall or snowmelt event can occur uniformly over a watershed of this size,

2. the hydraulic complexity of the system; ie. lake and channel routing effects are variable over time and are different in different parts of the watershed.

There is no feasible way to eliminate these errors, and hence the results of the regression analysis were adopted for estimating flows in the period prior to streamflow records at the five study sites.

6. FIELD SURVEY AND RESULTS

To provide data required for calculating lake outlet rating curves at several sites, a brief field survey program was undertaken in June 1981. This program included a general reconnaissance of the watershed and outlet surveys at the required sites.

A total of 12 lake outlets were surveyed. These sites were at lake outlets that were to be included in the model and that had little or no data on which to base rating curve calculations.

The outlet survey at each site generally included three cross-sections, a longitudinal slope survey, survey of hydraulic controls (weirs, beaver dams, etc.), survey of lake elevation, and estimation of discharge.

Surveys were done to geodetic elevation at those sites where benchmark elevations were available from the Surveys Branch of Alberta Environment. At six sites, a local datum elevation of 100.0 m was assumed.

Lake outlets that were surveyed were the following:

Lake	Datum	Notes
Caribou	local	- discharge 1.5 cms
Moose	geodetic	- rock weir - low discharge (0.007 cms)
Manatokan	geodetic	- beaver dam at outlet (partially broken)
Tucker	local	- rock-filled timber weir and 2 beaver dams

Burnt	local	- 2 beaver dams at outlet
May	local	- no discernible flow - 2 beaver dams at outlet
Marie	geodetic	- no discernible flow - 3 beaver dams at outlet
Muriel	geodetic	- no flow
Charlotte	local	- road crossing with 3 culverts (one gated)
Reita	geodetic	- no flow
Angling	geodetic	- low discharge (0.03 cms)
Primrose	local	- well-defined outlet channel - discharge 4.8 cms

Several observations resulting from the field survey are as follows:

- many of the lakes in the project area have poorly-defined outlets or have beaver dams at their outlet. As a result, it is not possible to define an accurate outlet rating curve at many of the lakes, and furthermore, the outlet rating characteristics are subject to periodic and unpredictable changes due to construction and destruction of beaver dams;

- lakes in the study area display evidence of only a small range in water level fluctuation;

- except for Primrose and Caribou Lakes, all had very low or no outflow at the time of survey;

- one local resident commented that he had seen no outflow from Muriel Lake in the last 30 years.

The accuracy of this report is suspect, but there is likely some truth to it in that outflows have likely been sporadic and of low magnitude.

Selected photos at each of the lake outlets and on the Beaver River are shown in Photos 1 to 12.

The survey results were used in the calculation of lake outlet rating curves as will be discussed later.

7. THE SSARR ROUTING MODEL

7.1 Objectives

As noted in Section 4, the basic objective of the computer routing model was to calculate streamflows and lake levels at the 20 study points for which there is only a very limited amount of measured hydrometric data. In addition, runoff data and lake outlet rating curves were to be provided to Nanuk Engineering and Development Ltd. for use in the water balance model.

7.2 Model Overview

The computer program used for the routing model is the Streamflow Synthesis and Reservoir Regulation program (SSARR).

The SSARR computer program was developed by the U.S. Army Corps of Engineers, North Pacific Division, for operational use in hydrologic engineering studies and daily streamflow forecasting. It is comprised of two basic components:

a) a generalized watershed component for synthesizing runoff from snowmelt and rainfall;

b) a river system component for routing streamflows from upstream to downstream points. The river system component is designed to simulate the routing and travel of runoff flows through a lake and river system. It can be configured to simulate lake storage and routing as well as the routing or travel of water through a river reach.

For the purposes of the present study, only the second component, the river system/reservoir regulation model, was used.

For specific details on the computer program, the reader is referred to the program user's manual, Reference 2.

A basic schematic of the river system model is given in Figure 3. The principal components in the computer model include:

- local area runoff or inflows
- lakes
- channel reaches
- sum points or nodes

The schematic does not show direct lake evaporation/precipitation, nor does it show the dummy or artificial volume balance reservoirs that were used for determination of simulation errors.

The final model data and details of their derivation are described below.

7.3 Model Data

7.3.1 Local Area Runoff

The most fundamental or elementary unit of watershed area in the model is the local drainage area, or simply local area. It is a small portion of the watershed that is considered to yield runoff into lakes or river reaches.

An outline of the local areas included in the model is given in Figure 2, and drainage areas are tabulated in Table 2.

For purposes of the SSARR model, runoff hydrographs for local areas were estimated by comparison or analogy with gauged watersheds having similar runoff characteristics. Streamflows for ungauged local areas were estimated as a percentage of the gauged streamflows based on the size of the local area and an estimate of its annual runoff depth. This procedure will be discussed below with reference to Figure 18.

In Figure 18 local areas that are judged to be of similar hydrologic character or to have similar streamflow patterns on the basis of similarities in location, soils, vegetation and land use are shown as dots of the same colour. The colored lines depict the outlines of sub-basins; these are larger areas for which runoff records are available.

For example, consider sub-basin 516 (it includes local areas 116 and 117). The runoff from the sub-basin is represented directly by the second-order streamflow gauge on Jackfish Creek (sum point 516). On the assumption that local areas 116 and 117 are hydrologically similar and have the same annual depth of runoff, their daily flows were estimated as a percentage of gauged flows for sub-basin 516. These percentages were calculated as the ratio of local drainage area to the total drainage area at the Jackfish gauge[1].

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1 Runoff percentages for local areas 116 and 117 were increased slightly after initial calibration runs to compensate for evaporation losses on Tucker Lake.

The sub-basin boundary and the local areas are shown in the same color in Figure 18 to depict the assumed similarity in hydrologic characteristics.

Runoff flows for local areas 104, 105 and 107 were estimated as a proportion of drainage area of sub-basin 907. This sub-basin consists of the watershed tributary to the Sand River upstream of the Wolf River plus Fisher Creek. The three local areas are physiographically similar and were assumed to be hydrologically similar.

Streamflows for sub-basin 907 have not been measured directly, but can be calculated from recorded flows at the second-order Sand River gauging station (sum point 508) by subtracting runoff flows from local area 108 (Punk and Seibert Creeks) and sum point 506 (Wolf Lake outlet).

Streamflows at sum point 506 are given directly by streamflow records and the correlation analysis discussed earlier. Assuming that Punk and Seibert Creeks have similar runoff characteristics and the same annual depth of runoff as does the watershed upstream of the Wolf Lake outlet[2], daily flows from local area 108 can be estimated as a proportion by drainage area of daily flows at sum point 506.

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2 The validity of this assumption cannot be proven in the absence of streamflow records. It appears reasonable because of similarities in watershed physiography, nearness of the watersheds, and the presence of large lakes in all three watersheds.

Since the drainage area of local area 108 is 1.06 times as large as the drainage area of 506, the calculation of streamflows for sub-basin 907 can be expressed as:

$$Q_{907} = Q_{508} - 2.06\ Q_{506}$$

Calculation of local area flows in sub-basin 930 (the lower Beaver River sub-basin) is somewhat more complicated than in the other sub-basins because the local areas fall within substantially different physiographic regions and could therefore be expected to have substantial differences in runoff characteristics. This sub-basin includes forested regions tributary to Marie Creek and agricultural land tributary to the Beaver River.

The net daily flows from sub-basin 930 were calculated as the difference between the lower Beaver River gauge (526) and the upstream Beaver, Sand and Jackfish gauges (502, 508, 516). In this calculation a travel time of two days was adopted from the Sand and the upstream Beaver gauge to the lower Beaver gauge, and a travel time of one day was adopted from the Jackfish gauge to the lower Beaver gauge.

The calculation of local area flows in this sub-basin was made as follows:

1. An analog sub-basin was selected. The analog sub-basin is the one which has a seasonal pattern of runoff most similar to the desired local area (usually the closest or most physiographically similar);

2. Daily flows at the analog station were multiplied by a local area yield factor that included the ratios of drainage areas and annual runoff depths, i.e.

$$\text{Factor} = \frac{Q_{local}}{Q_{analog}} = \frac{A_{local}}{A_{analog}} \times \frac{R_{local}}{R_{analog}}$$

where: Q = discharge
A = drainage area
R = runoff depth

For each local area, the annual runoff was estimated or assumed by comparison with the runoff data in Table 1.

An identical procedure was used to estimate local area flows downstream of the Beaver River gauge (526) and in the Medley River (local 132).

Analog stations, estimated annual yields, and computed yield factors for each local area are given in Table 3. Analog stations used for the various local areas are depicted graphically in Figure 18.

Inflows into Cold and Primrose Lakes (locals 131 and 133) were calculated from Cold Lake outflows by means of a reverse lake routing procedure. This procedure is similar to a standard lake routing analysis except that it calculates inflows from outflow data rather than the reverse. These local area flows were computed as net inflows, i.e. inflow minus lake evaporation and precipitation. This calculation included the following steps:

1. Route Cold Lake outflows backward through an artificial aggregate lake (area equal to Cold plus Primrose, with Cold Lake outlet rating curve).

2. Subtract local 132 (Medley) estimated as 13% of station 907.

3. Add net evaporation from the aggregate lake.

4. Proportion the result of step 3 on the basis of drainage area between local 131 and 133.

5. Subtract net evaporation from Primrose and Cold Lakes (as a percentage by lake area of the aggregate lake - step 3) from local 131 and 133 respectively.

Daily local inflows into Wolf Lake were also computed for use in the water balance model (not required in the SSARR model). The inflows were calculated from Wolf Lake outflow data (node 506), using the reverse routing procedure, and were calculated as net inflow to include Wolf Lake evaporation and precipitation.

7.3.2 Lake Precipitation and Evaporation

The water balance through each lake requires the addition of precipitation onto the lake surface and subtraction of evaporation from the lake surface (except for Cold, Primrose and Wolf Lakes for which net inflows were provided to include evaporation and precipitation).

For purposes of the SSARR model, daily values of lake precipitation/evaporation were computed with the following procedure:

1. estimate monthly evaporation using a modified form of Meyer's method (discussed further below) and assume evaporation rate is constant over the month;

2. subtract daily evaporation from daily precipitation to calculate net precipitation/evaporation;

3. convert net precipitation/evaporation to an equivalent flow rate in cubic feet per second into an artificial or reference lake of 200 square miles (518 km^2). This reference lake was designated model point 800;

4. compute individual lake precipitation/evaporation as a percentage of station 800 based directly on lake area (Table 4)[1].

The calculation of monthly evaporation rates made use of Meyer's method as outlined in Reference 3 combined with Morton's method as outlined in Reference 8. Meyer's method uses emperical relationships between monthly evaporation and air temperature, water vapour pressure, and wind speed, whereas Morton's method uses a more detailed energy budget approach. In the final model runs

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1 The lake size of 200 mi^2 adopted for station 800 is larger than any lake in the watershed and was adopted to permit all lake precipitation/evaporation percentages to be less than 100%.

the monthly values computed with Meyer's method were adjusted to total the annual values predicted with Morton's method[2].

7.3.3 Lake Routing Characteristics

For simulation of the lake routing process, the computer model uses an elevation-storage-discharge table for each lake. This table represents the relationship between lake elevation, outflow rate, and storage volume, and is used in simulating the lake water balance.

The storage volume for each lake was estimated from the nominal lake water area (Table 4), assuming a circular lake with shoreline slopes of 10 horizontal to 1 vertical. This procedure is only approximate, but is thought to result in only small errors in most cases if the range in water level fluctuation is relatively small.

Lake storages were defined to have a zero value at the elevation of the lake outlet sill. Elevations above the sill were assigned positive values of storage and elevations below were assigned negative values.

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2 Monthly values computed with Morton's method were used in early model runs but were found to over-estimate annual evaporation. Experience with the two methods of calculating lake evaporation seems to indicate that Morton's method gives more reliable estimates of annual totals but less reliable estimates of monthly variation. Hence the hybred approach described above was adopted.

Outlet discharge rating curves were determined from the following (in order of decreasing priority):

- Water Survey of Canada rating curves
- Alberta Environment rating curves
- Stanley Associates Engineering Ltd. rating curves
- hydraulic computations based on surveys conducted by Northwest Hydraulic Consultants Ltd., Alberta Environment, and Stanley Associates Engineering Ltd.

Two factors affect the reliability of the outlet rating curves and should be kept in mind in interpreting the study results. The first is non-stationarity of the rating curves, i.e. the outlet rating characteristics of a lake can change from time to time due to changes at the lake outlet such as erosion of the outlet channel, construction or destruction of beaver dams (e.g. Ethel Lake), and construction of man-made controls (e.g. rock weir at Moose Lake outlet and constructed channel at Reita Lake outlet). In all cases except Ethel Lake the rating curves were based on conditions that existed in early 1981. On Ethel Lake a lake level control weir was constructed in 1980 and the rating curve used in the model was based on conditions that existed between August 1978 and March 1980.

The second factor that affects the quality of the computed rating curves is the limited amount of field data at several sites which was sufficient for only approximate calculations.

Because of these two factors, the rating curves used in this study should be considered a first estimate

only, subject to change with time and subject to field confirmation with discharge measurements.

A summary of the source data used in developing outlet rating curves is presented in Table 5, and the outlet rating tables are included in the model data listing in Appendix A.

7.3.4 Channel Reaches

The river model also simulates streamflow routing through channel reaches. It simulates storage and lagging effects in river reaches with Wilson's storage routing equation (Reference 2).

The routing method requires two coefficients (KTS and n) to describe the routing characteristics of a channel reach. In the present study an approximate method of estimating KTS and n was developed from an analysis of Water Survey of Canada gauge rating curves as follows:

1. Flow velocity was plotted against discharge for each gauge site (Figure 19) to yield estimates of the coefficient n (the exponent in the equations fitted to the data in Figure 19). The curves have a common value for n equal to 0.5 which was adopted for all channel reaches in the study.

2. Values of k_1 (the constant in the equations in Figure 19) were plotted against the drainage area of each gauge (Figure 20). The fitted curve in Figure 20 was adopted to calculate the coefficients k_1 and KTS (defined by $KTS=k_1 L$ where L is the length of reach) for all study reaches.

Each reach in the model was divided into a number of lengths or phases of 8 to 11 km in length (5 to 7 miles), in accordance with Corps of Engineers recommendations.

Values of KTS, n and number of phases adopted in the model are provided in the model data, Appendix A.

7.3.5 Sum Points

Sum points in the model (also called transfer points) represent nodes or confluences in the river system. They provide a location for input or output of discharge and lake level data into the model.

7.3.6 Dummy Reservoirs

A number of artificial or "dummy" reservoirs are included in the model for the purpose of calculating the amount of simulation error and providing an overall check on volumes of runoff. These dummy reservoirs are defined in such a manner that every foot of storage or reservoir elevation represents one inch of basin runoff in the corresponding watershed basin.

The dummy reservoirs are essentially "invisible" to the user of model output in that they are provided for computational purposes only. Consequently they have not been shown on the model schematic. They have been included in the model data listing (Appendix A) and in the calibration output (Appendix B).

7.3.7 Initial Conditions

The operation of the model requires that initial or starting levels of discharge and lake elevation be specified at the start of the simulation period (January 1, 1956).

Without measured data it is not possible to determine initial conditions directly so they must estimated indirectly. Consequently the initial conditions at the start of run may be substantially in error although in most cases the errors tend to damp out within a few weeks. On larger lakes (e.g. Cold and Primrose Lakes) or in connected lakes (e.g. upper Marie Creek watershed), the initial error may persist for some time, possibly up to a year or more.

In the present study, a first run was made to establish initial conditions for the start of simulation. Lake levels and discharges computed at the end of December 1974 in the first run were taken as a first estimate of January 1956 conditions. These estimates were then adjusted on the basis of gauged streamflows in the Beaver River at Cold Lake for January 1956 to give the initial conditions finally adopted in the model.

7.3.8 Data Listing

A complete copy of the final model data including sample streamflow input data for the 1956 to 1980 period is provided in Appendix A. A complete disc file was provided to Alberta Environment, containing the computer program, the model data, all streamflow input data, and a

complete set of computer procedure commands required for operating the model. This file was provided under separate cover.

7.4 Model Results

Model results were provided under separate cover to Alberta Environment, and included the following:

- discharge and lake stage hydrographs;
- flow/elevation frequency and flow/elevation duration curves;
- tables of daily flows and lake elevations and historical summaries.

A sample of the discharge hydrographs is given in Figure 4 for the Beaver River at the Water Survey of Canada gauge site (526), and three flow frequency curves (minimum, mean and maximum flow frequency curves) and one flow duration curve for the same site (526) are provided in Figure 21. The significance of the flow frequency and duration curves is discussed below.

The minimum annual flow frequency curve (top left of Figure 21) indicates the frequency with which the annual minimum flow was lower than a certain value; it indicates that only one year in 25 (4% of the years) had a day of flow that was lower than about 0.4 m^3/sec. Conversely, the maximum annual flow curve (upper right in Figure 2) shows the frequency with which the annual peak flow exceeded a given value; for example, that a daily

flow of about 600 m^3/sec or more occurred in only one of the 25 years.

The mean annual flow frequency curve (top centre of Figure 21) shows that the annual flow (ie. the average over the whole year) was greater than about 60 m^3/sec once in 25 years (4% of the years) and that it was greater than about 8 m^3/sec in 24 of the 25 years (96% of the years). The median annual flow (50% frequency) was about 25 m^3/sec.

The frequency curves can be used as probability curves to predict the occurrence of more severe events, as is done in a flood frequency analysis. In a flood frequency analysis, a probability distribution is assumed and is "fitted" to the plotted data. The distribution for floods is commonly assumed to be a log-normal distribution and the curve can be fitted by eye or by means of a statistical routine. Once this is accomplished, the curve can be extrapolated (with caution) beyond the range of observed data to predict a more severe event.

In the above example, a fitted curve (by eye) is shown on the maximum flow frequency curve. Extrapolating to a 1:100 frequency (1% probability) gives a flood estimate of about 850 m^3/sec.

The flow duration curve shows the frequency with which daily flows exceeded a certain value when all flows are considered (rather than the annual minima, maxima, or means as in the case of the flow frequency curves). For example, it shows that half of all days in the period (50%) had a daily flow of 25 m^3/sec or greater. The highest and lowest daily flows in the whole period of record are also shown on this graph.

It should be noted that the finest resolution achieved in the model output is 0.03 m^3/sec (1.0 cfs). Zero flows or flows less than 0.03 m^3/sec are plotted as 0.001 m^3/sec for the 20 modelled sites (effectively 0.0 m^3/sec).

An example of a lake elevation plot (stage hydrograph) is given in Figure 22 for Cold Lake (study point 533), and elevation frequency and duration curves are given in Figure 23 for the same site.

8. DISCUSSION OF RESULTS

The following is a discussion of the reliability and quality of the computed flows and water levels at the 27 study sites.

8.1 First-Order Hydrometric Gauge Sites

At two study sites (533 and 526), flows and water levels were based directly on hydrometric records for the entire 25-year period. Consequently the reliability of study results for these two sites is high and is limited only by the accuracy of the discharge and water level measurements (generally accurate within a small percentage).

8.2 Second-Order Streamflow Gauge Sites

Five of the study points are located at second-order hydrometric gauge sites (study points 506, 508, 103, 502 and 506). Discharges at these sites have been recorded since about 1970. For the period prior to 1970, discharges were estimated with the correlation analysis as described in Section 5 of this report.

Discharges calculated with the correlation analysis are subject to uncertainty due to scatter or imperfect fit in the correlation relationships between the second-order stations and the first-order station on the Beaver River at Cold Lake. As demonstrated earlier, there may be substantial variation in individual runoff events even though there appears to be a strong and generally

consistent relationship between the stations. This variation is not surprising, given the variability of rainfall and snowmelt within a basin as large as the Beaver River basin, but it can lead to substantial differences in individual daily flows.

A second source of uncertainty is that correlation relationships were extrapolated outside the range of measured data used in the correlation and were assumed to be constant with time. It was assumed without means of verification that the relationships developed on the basis of streamflows recorded since 1970 are applicable to the earlier period. Because of land use changes in parts of the watershed over time and natural variability in the hydrologic cycle, this assumption may not be strictly valid. In particular, the earlier period included a drier year (1968) and a wetter year (1962) than occurred in the period of record and hence the computed discharges would be less reliable in those periods. In addition, it would appear that winter flows were consistently lower in the period prior to 1970 than in recent years (see Figure 4) and it is not certain whether the correlation relationships are reliable for the lower flows.

There are no hydrometric records in the watershed with which to confirm the computed results directly. Prior to 1970, discharge measurements were made only for the Beaver River at Cold Lake. It is possible to achieve only general confirmation by comparing the recorded discharges with the discharges computed by the model at that location. This comparison is made in Appendix B and demonstrates good agreement for the entire period with no apparent differences between the 1956 - 1970 period and

the 1970 - 1980 period. The total runoff computed over the 25 year period was 2.6% higher than the measured runoff. This comparison gives some confidence to the computed flows.

8.3 Other Sites

At the 20 sites where flows and water levels were computed by modelling, the reliability of the computed results is even more variable and more difficult to quantify. The only measure of accuracy is given by the small amount of recorded data at those sites within recent years.

A visual assessment of reliability at these sites is given in Figures 24 through 34 in which computed water levels and discharges are plotted along with recorded data. No lake level or discharge records are available prior to 1970 and the data since 1970 are adequate for only a general definition of water levels and flows.

The available lake elevation data shows reasonably good agreement with computed levels at all sites. There is a general agreement in seasonal variation (ie. computed levels rise more-or-less as they should) and computed water levels are generally within about 0.1 to 0.2 m of the recorded levels.

During several periods there is poor agreement; in 1973 on Moose Lake, winter 1974 on Manatokan Lake, winter 1977-78 on Marie and Ethel Lakes and the 1978-79 period on Augling Lake. The maximum deviation is 0.4 m on Moose Lake, 0.7 m on Manatokan Lake, 0.3 m on Marie Lake,

0.6 m on Ethel Lake and 0.4 m on Angling Lake. In each of these periods the recorded levels were higher than normal and were higher than the computed levels, suggesting that recorded levels were affected by construction of beaver dams (this is known to be true on Ethel Lake).

Recorded discharge data are even less dense than lake elevation data, and consist only of miscellaneous discharge measurements and annual peaks at the outlet of Manatokan Lake since 1971 and occasional discharge measurements downstream of Marie, Ethel and Primrose Lakes and on the Medley River since 1977.

There is good agreement between observed and computed flows at Primrose Lake and Manatokan Lake outlets and on the Medley River, although the model appears to over-estimate dry period flows on the Medley. There is no consistent comparison at Marie Lake and Ethel Lake outlets (note that the recorded flows for Marie Lake were measured some distance further downstream and hence include some downstream runoff). The model appears to under-estimate in 1978 for these two sites, to overestimate in 1980, and to give good comparison in 1979. However, it is difficult to assess the significance of these differences, given the short length of record and the fact that recorded discharges are affected by beaver damming activity in 1978 and by operation of the Ethel Lake control structure in 1980.

There are no discharge measurements in the Moose, Muriel and Reita basins. Consequently the computed flows and lake levels should be used with caution. These basins have a large area of lake relative to the size of the contributing watershed (Moose, Muriel and Reita Lakes) and

as a result lake evaporation is a significant percentage of total lake inflow in these areas. Consequently computed streamflows and lake elevations are sensitive to small errors in estimating either evaporation or inflow.

One of the most significant factors that affects the computed and recorded levels above is the effect of beaver damming on lake outlet characteristics. It is known that beaver dams presently exist at a large number of the smaller lakes included in the model, and it is likely that beaver dams have existed at other lake outlets in the past. These beaver dams have significant hydrologic impacts because they can cause substantial changes in lake levels and outlet flows, and furthermore they are variable over time as dams are constructed, raised, aged, or destroyed. Consequently, a "random" effect is introduced into the hydrologic cycle; it is an effect that cannot be related to other hydrologic events except in a general fashion.

An example of the effects of beaver damming at a lake outlet is at Ethel Lake for which beaver dam effects over the past seven years have been documented in a report by Stanley Associates Engineering Ltd. (Reference 6) and in a subsequent report by Northwest Hydraulic Consultants Ltd. (Reference 7). High water levels in the winter of 1977-78 (see Figure 27) are known to have resulted from a dam at the outlet; these water levels are about 0.5 m above the normal winter level recorded in other years, in spite of the fact that 1977 was the year of second lowest runoff in the study basin during that period. As pointed out in Reference 7, this results in a temporary storage of runoff water that can be as great as 30% of the total annual runoff at that point, which can affect flows and

water levels well downstream in the system as well as on Ethel Lake itself.

Other than temporal effects introduced by beaver damming activity, the study results appear to be reasonably reliable.

Other effects are apparent on Ethel Lake in 1980, due to the construction of a control weir at the lake outlet. High lake levels (relative to previous winters) occurred in winter of 1980 when the runoff was the lowest of the seven years.

8.4 Evaluation of Results

On the basis of experience gained with the basin in the course of this study, it is possible to make a subjective assessment of the reliability of the results for use in planning studies. This assessment is summarized as follows (see below for definition of ratings:

	Study Point	Flows	Water Levels
Sand River			
Caribou Lake	204	G	G
Sand River above Wolf River	505	G	-
Wolf Lake	506	G-E	G-E
Sand River at Truman	508	G-E	-
Mooselake River			
Moose Lake	210	G	F
Manatokan Creek			
Manatokan Lake	212	G	F

	Study Point	Flows	Water Levels
Jackfish Creek			
Tucker Lake	216	G	F
Jackfish Creek at mouth	516	G-E	-
Marie Creek			
Burnt Lake	218	F	F
May Lake	219	F	F
Marie Lake	220	F	F
Ethel Lake	221	F	F
Marie Creek at mouth	521	F	-
Muriel Creek			
Muriel Lake	223	F	F
Muriel Creek at mouth	525	F	F
Reita Creek			
Reita Lake	227	F	F
Angling Lake	228	F	F
Reita Creek at mouth	529	F	-
Cold River			
Medley River	132	F	-
Primrose Lake	231	G	GW
Cold Lake	233	E	GW

Definitions:

E - Excellent quality; based directly on recorded flows; useful for all purposes

G - Good quality; main stem flows based on correlation analysis and modelling; not sensitive to modelling assumptions; useful for planning purposes; dry periods less reliable with no verification data

F - Fair quality; based on modelling with little verification data; sensitive to modelling assumptions and beaver damming and other temporal effects; good general agreement with substantial variation in specific events; useful for planning purposes with caution

W - Shoreline locations are subject to wind set-up effects.

These subjective evaluations above are based on our experience and familiarity with the basin gained in the course of this study and on the limited amount of hydrometric data available. In the above definitions, planning purposes are considered to include water resources allocation studies at the planning level, as opposed to design studies or regulation of water users.

9. CONCLUSIONS

The Surface Water Supply Study as described above has provided a synthetic 25-year record of streamflows and lake elevations at 27 points within the Beaver River - Cold Lake Study area, and has provided a computer model of the river system that can be readily updated in the future as additional hydrometric data become available.

As discussed earlier, the reliability of the present estimates of water levels can be demonstrated at several locations where lake levels have been recorded periodically within the past ten years. The computed lake levels are generally within 0.1 to 0.2 m of the recorded levels, except for several periods when beaver damming activity that is not simulated in the model is suspected of having affected the recorded levels.

The reliability of the present estimates of streamflow is more difficult to establish with the present data base because the streamflow records presently available are too sparse to yield meaningful comparisons. It is felt that the long-term trends are simulated well, but that short- term trends are influenced strongly by temporal effect that cannot be simulated precisely, such as beaver damming effects and variability of storm events over the watershed.

Until such time that additional streamflow data are available to confirm or refine the streamflow and water level estimates, the model results should be used with caution.

Additional hydrometric data will be required to update the model parameters and to confirm the validity of

the model results more definitely. Model refinements will be possible in two areas:

1. refinement of local area runoff calculations. As additional streamflow data are collected in the watershed, it may be possible to refine the estimates of local area runoff and to confirm them with recorded discharges.

2. refinement of lake outlet rating curves. Several of the outlet curves were based on a minimum of data and consequently they are subject to significant error. Improvements may be possible with a more extensive program of surveys and lake level/discharge measurements. Any future changes in outlet conditions will be detected with more frequent surveys; and can then be reproduced in the model. It should be noted however, that historic effects of beaver damming construction and destruction cannot be reconstructed.

Collection of the required hydrometric data will entail a fairly substantial committment of effort and funds because the gauges would have to be operated continuously over a period of two to three years or more to achieve a significant improvement. These data would be of direct use in the planning process and would also provide a basis for confirming or refining the model. It is our view that a small number of streamflow and lake elevation gauges located in the most critical or important areas of the watershed would give useful data.

Selection of specific gauge sites is beyond the scope of this report.

The effects of beaver dam construction and destruction on lake levels and stream flows has been noted above. It is not clearly understood how the overall effects of beaver damming influence the hydrologic cycle nor how the construction and destruction cycles are influenced by the hydrologic cycle, except in a general way. There may be grounds for research in this area.

In the early stages of project planning, two stages of modelling were considered. They were:

- a routing model (the present study), to simulate hydraulic routing through lakes and stream channels. Runoff hydrographs (into lakes and stream channels) for this stage have been estimated from gauge records by analogy or correlation;

- a runoff-routing model. This second stage model would be built on the first stage model and would involve synthesizing inflow hydrographs with a watershed runoff model. The watershed runoff model would be based on a detailed simulation of the runoff process, including precipitation, snowmelt, infiltration and soil moisture balance and three-phase routing (surface, runoff, interflow and groundwater flow).

It was intended that a decision to implement the runoff model would be based on the findings of the present study, as it was felt that the runoff process would be better understood at this stage and that the feasibility of runoff modelling could be better assessed.

It is our present opinion, at the conclusion of the routing model operation, that the runoff model would

require an extensive amount of data that is not available within the watershed. The data, required for simulation, calibration and verification, include meteorological data, soils data, and an extensive amount of runoff data. None of this data is more extensive, complete, or better distributed within the watershed than the basic streamflow data that has been used as input to the routing model. Consequently the results of a runoff model, in the absence of an extensive data base, would not be more reliable than those of the routing model used in the present study.

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TABLE 1

RUNOFF ESTIMATES IN THE STUDY BASIN

BASIN	NET[1] RUNOFF (mm)	SURFACE RUNOFF (mm)	SOURCE
BEAVER RIVER BASIN			
Sand R. above Wolf R.	104	104	AE Reference 4[2]
Wolf R. above Wolf L. outlet	71	94	AE Reference 4
Marie Cr. above Ethel L.	44	71	SAEL revised (Reference 5)
Marie Cr.-Marie L. to Ethel L.	22	70	SAEL revised (Reference 5)
Jackfish Cr. above WSC gauge	45	54	NHCL from WSC data
Amisk R. above WSC gauge	58	nd	NHCL from WSC data
Beaver R.-Amisk gauge to Goodridge gauge	46	nd	NHCL from WSC data
Beaver R.-Goodridge gauge to Cold L. gauge	36	48	AE Reference 4
Columbine Cr.	43	43	AE Hydrology Branch
COLD RIVER BASIN			
Primrose L.	85	125	NHCL from SAEL data
Cold L.-Primrose L. to Cold L. outlet	91	125	NHCL from SAEL data
ADJACENT BASINS			
Dillon R. above WSC gauge	138	nd	NHCL from WSC data
Beaver R.-Cold L. gauge to Dorintosh gauge	51	nd	NHCL from WSC data
Atimoswe Cr.	17	26	AE Hydrology Branch

1 Surface runoff is defined as runoff from land surfaces into lakes. Net runoff is surface runoff minus net lake evaporation.

2 AE - Alberta Environment Hydrology Branch
SAEL - Stanley Associates Engineering Ltd.
NHCL - Northwest Hydraulic Consultants Ltd.
WSC - Water Survey of Canada
nd - not determined

TABLE 2

LOCAL DRAINAGE AREAS

LOCAL AREA	DRAINAGE AREA km^2	mi^2
101	2311	854
102	2500	965
103	549	212
104	1386	535
105	1728	667
106	694	268
107	308	119
108	772	298
109	119	46
110	754	291
111	104	40
112	409	158
115	388	150
116	311	120
117	176	68
118	142	55
119	62	24
120	171	66
121	122	47
1211	181	70
122	254	98
123	303	117
124	181	70
125	233	90
127	54	21
128	148	57
129	47	18
130	62	24
131	3061	1182
132	300	166
133	2238	864
134	730	282

TABLE 3

LOCAL AREA RUNOFF ESTIMATION

LOCAL AREA	ESTIMATED ANNUAL RUNOFF (mm)	YIELD FACTOR AND ANALOG STATION
103	45	111% (516)
104	104	40.5% (907)
105	104	50.5% (907)
107	104	9.0% (907)
108	71	106% (508)
109	45	24% (516)
110	50	169% (516)
111	48	3.3% (930)
112	54	99% (516)
115	48	12% (930)
116	48	67% (516)
117	45	36% (516)
118	71	2.8% (907)
119	71	1.2% (907)
120	71	3.4% (907)
121	31	17% (516)
1211	48	5.7% (930)
122	48	8.0% (930)
123	50	68% (516)
124	50	41% (516)
125	48	7.4% (930)
127	50	12% (516)
128	50	33% (516)
129	48	1.5% (930)
130	48	2.0% (930)
132	104	13% (907)
134	51	25% (930)

TABLE 4

LAKE AREAS

LAKE	MODEL NUMBER	SURFACE AREA (km^2)
Caribou	204	4.2
Wolf	206	30.8
Moose	210	40.4
Manatokan	212	4.5
Tucker	216	6.5
Burnt	218	4.4
May	219	3.2
Marie	220	36.2
Ethel	221	4.8
Muriel	223	68.2
Charlotte	224	10.9
Reita	227	12.5
Angling	228	5.9
Primrose	231	445
Cold	233	349

TABLE 5

SOURCE DATA FOR LAKE OUTLET RATING CURVES

LAKE	DATA SOURCE	NOTES
Caribou	NHCL survey	
Wolf	WSC rating curve	converted to Geodetic with AE lake records
Moose	NHCL survey	weir control
Manatokan	NHCL survey and AE measurements	beaver dam
Tucker	NHCL survey	weir control and beaver dam
Burnt	NHCL survey	beaver dams
May	NHCL survey and AE measurements	beaver dams
Marie	NHCL survey and AE rating curve	beaver dams
Ethel	SAEL rating curve extrapolated	curve for conditions subsequent to August 1978
Muriel	NHCL and AE surveys	control at Landry Lake outlet
Charlotte	NHCL survey	culvert control
Reita	NHCL survey	constructed channel
Angling	NHCL survey	
Primrose	NHCL survey	
Cold	SAEL rating curve	

Note: NHCL - Northwest Hydraulic Consultants Ltd.
AE - Alberta Environment
WSC - Water Survey of Canada
SAEL - Stanley Associates Engineering Ltd.

Photo 1. Sand River at the outlet of Caribou Lake, looking upstream.

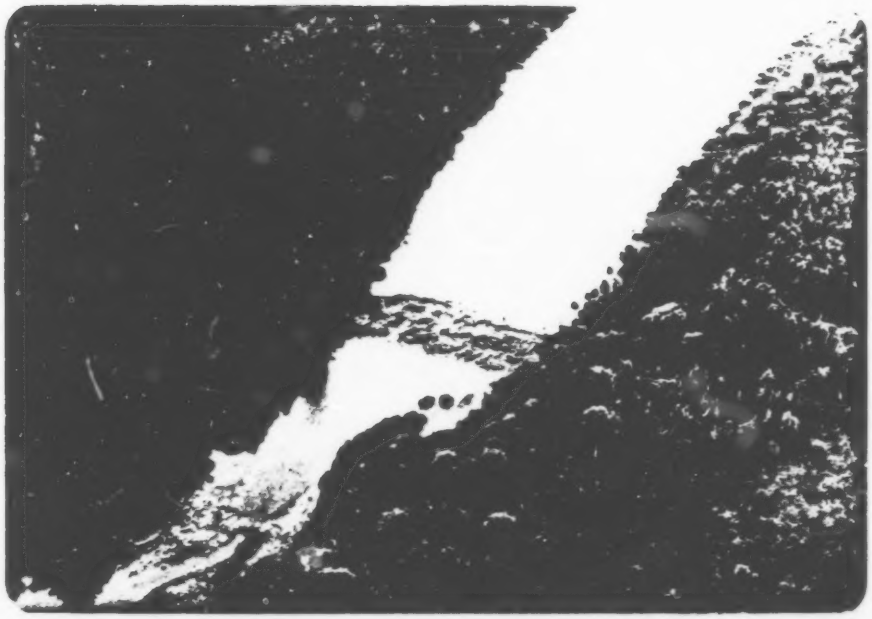


Photo 2. Rock weir at the outlet of Moose Lake (looking upstream).

Photo 3. Beaver dam at Manatokan Lake outlet (looking upstream).

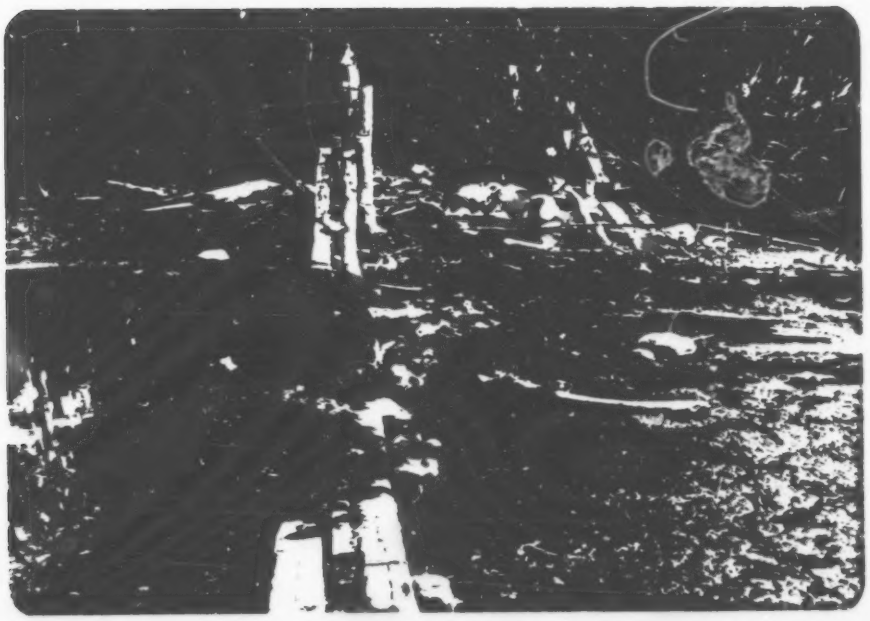


Photo 4. Weir at outlet of Tucker Lake.

Photo 5. Beaver dam at outlet of Burnt Lake.

Photo 6. May Lake outlet channel.

Photo 7. Beaver dam at Marie Lake outlet.

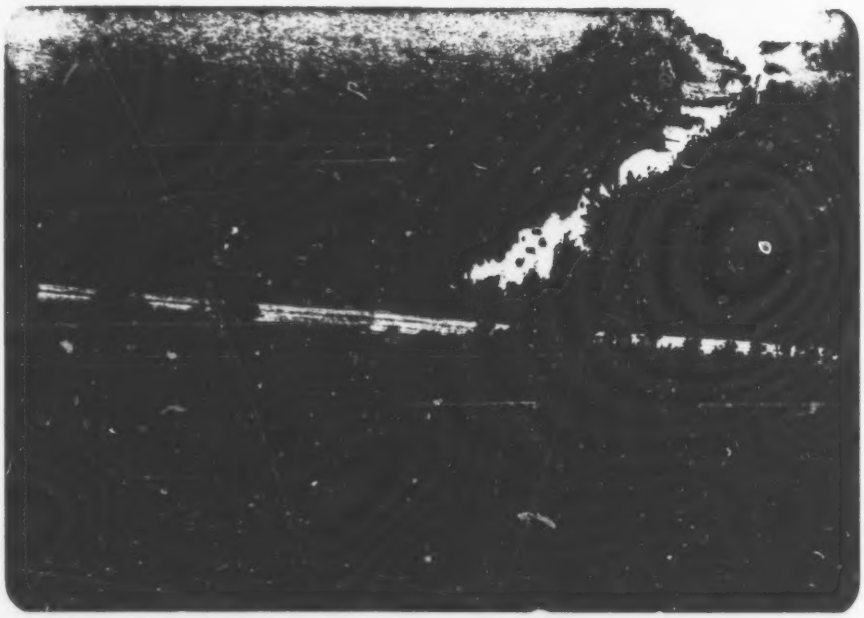


Photo 8. Landry Lake outlet (outlet control for Muriel Lake).

Photo 9. Culvert outlet control on Charlotte Lake.

Photo 10. Channelized outlet of Reita Lake.

Photo 11. Angling Lake outlet channel (Reita Creek).

Photo 12. Primrose Lake outlet channel looking downstream. (Martineau River)

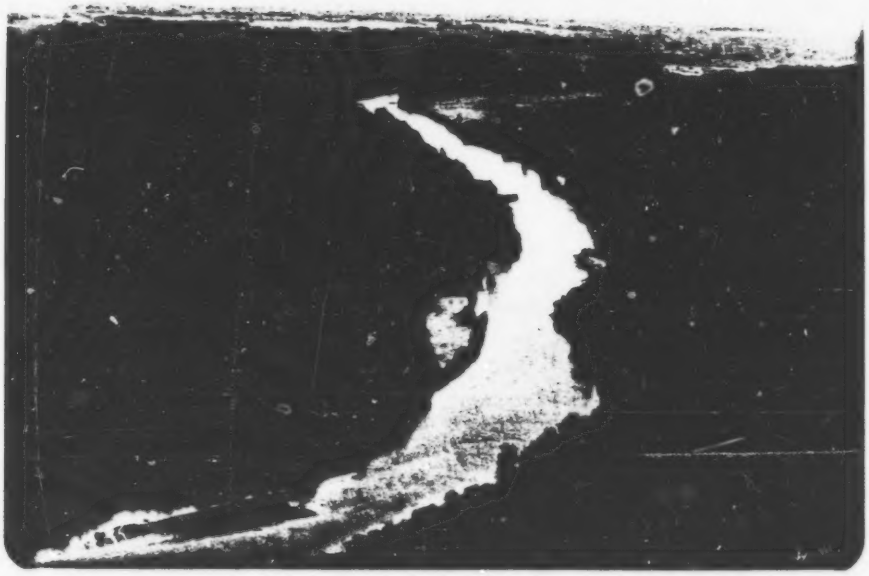


Photo 13. Beaver River downstream of Sand River.

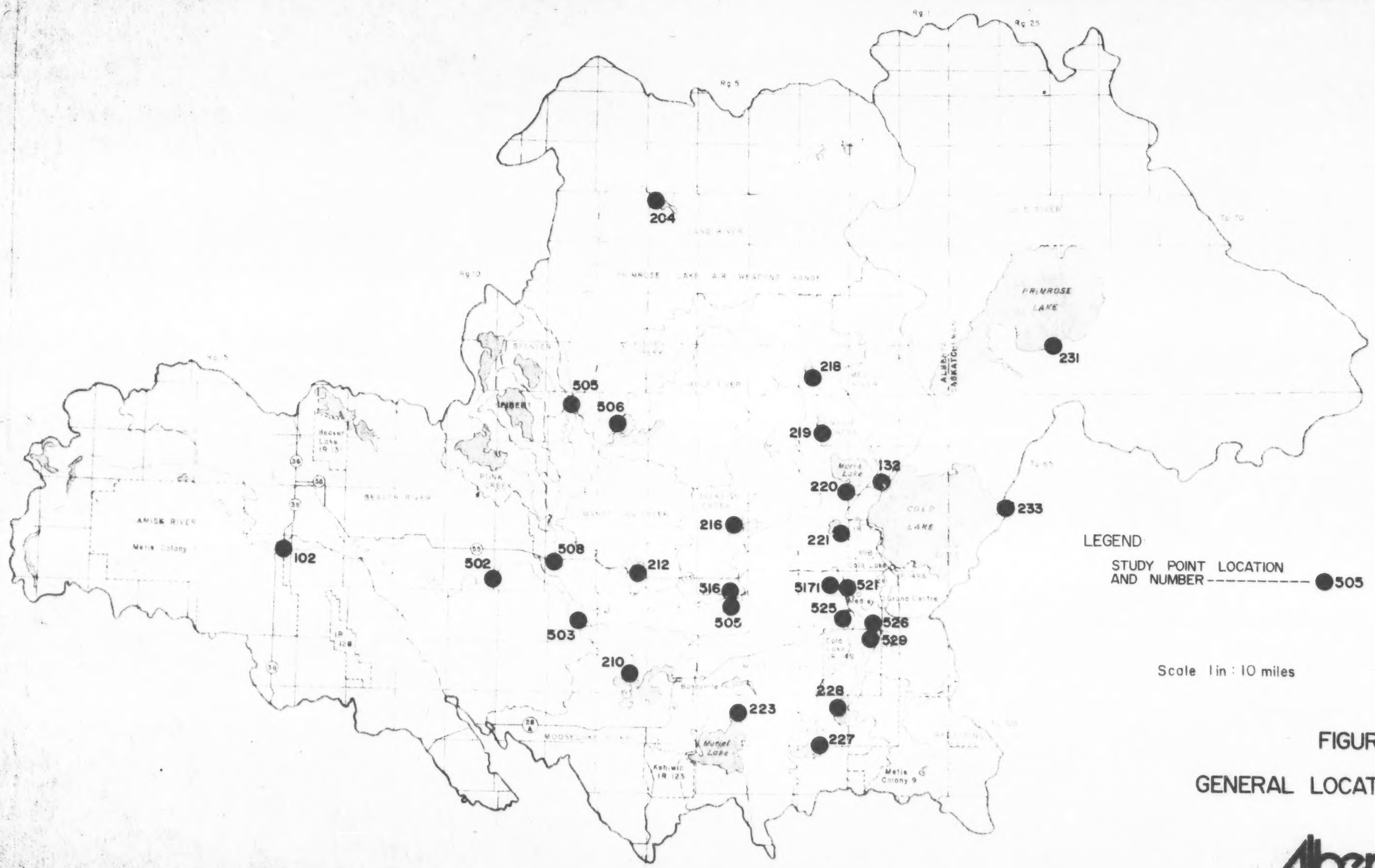
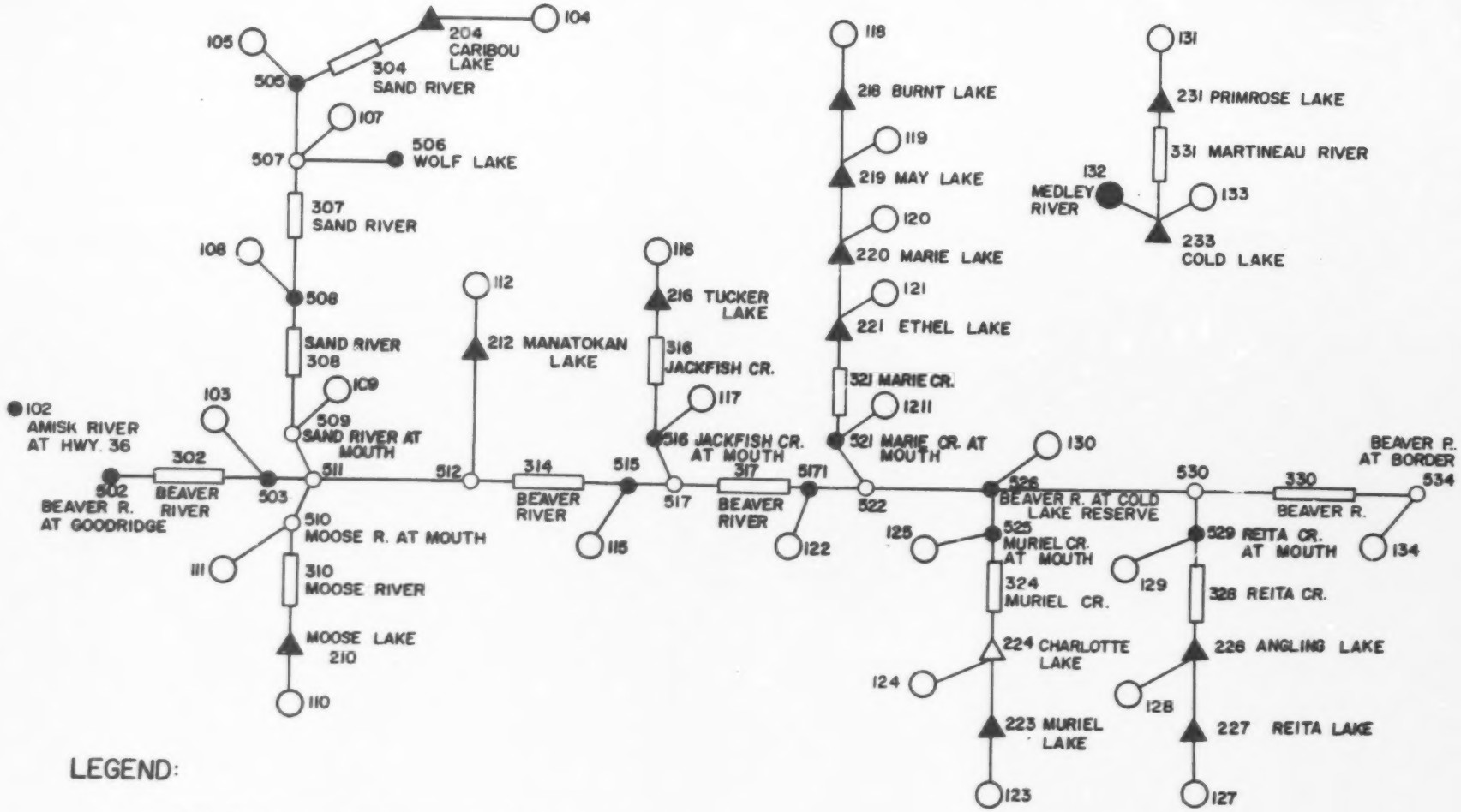


FIGURE 1

GENERAL LOCATION

Alberta
ENVIRONMENT
PLANNING DIVISION



LEGEND:

SUM POINT (CONFLUENCE OR NODE)— ○ 509

LOCAL INFLOW - - - - - - - - - - - - ○ 112

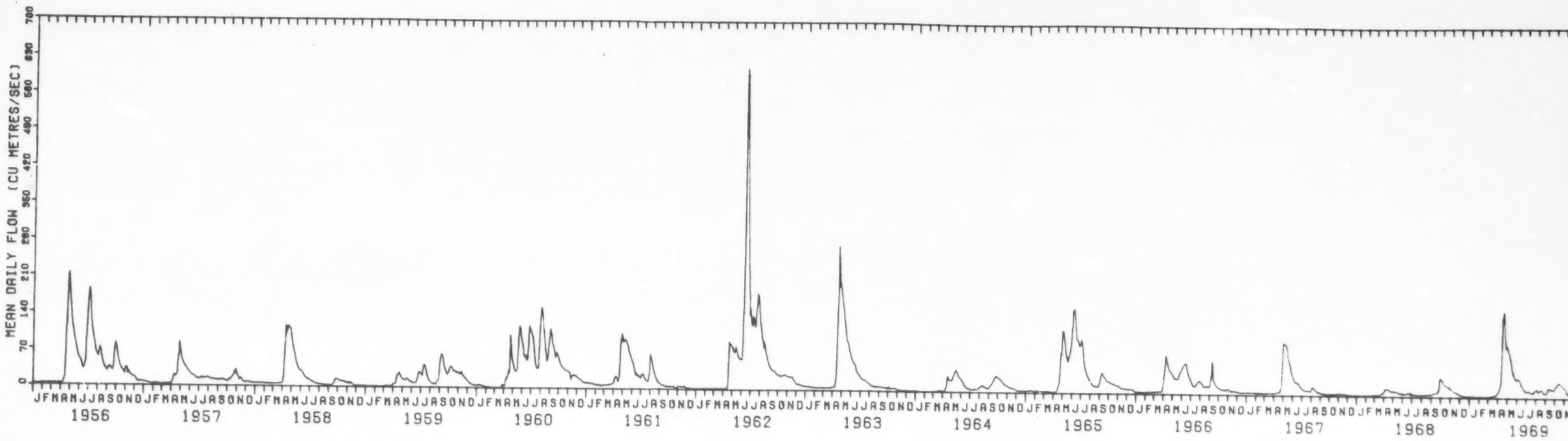
LAKE - - - - - - - - - - - - - - - - - - △ 212

CHANNEL ROUTING REACH - - - - - - - ▭ 308

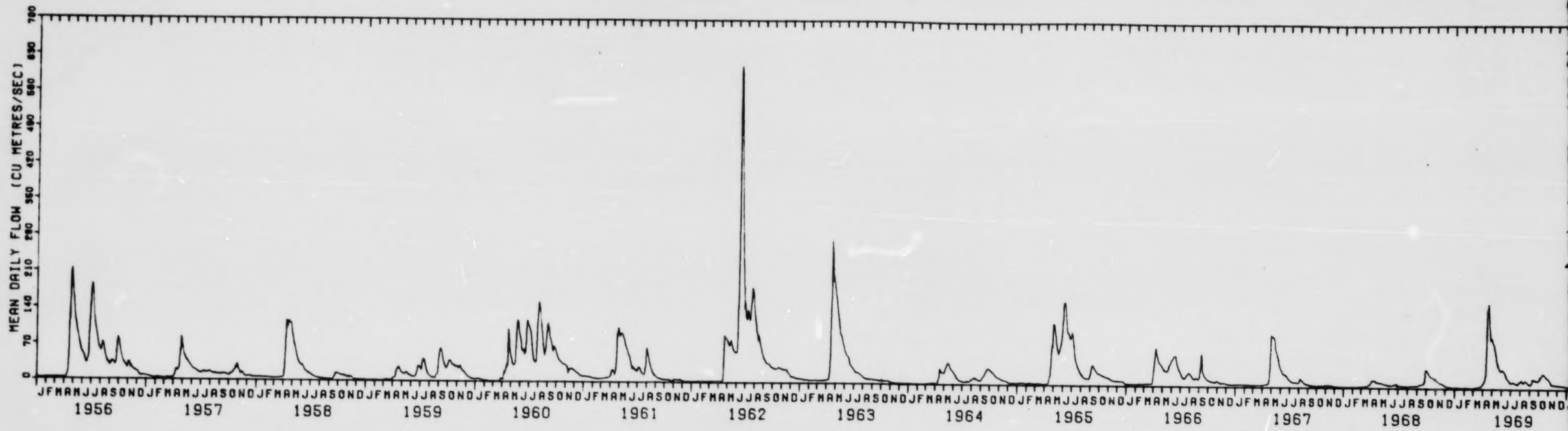
NOTE: DESIGNATED STUDY SITES ARE DARKENED.

FIGURE 3

WATERSHED SCHEMATIC



526 BEAVER R. AT W.S.C. COLD



526 BEAVER R. AT W.S.C. COLD

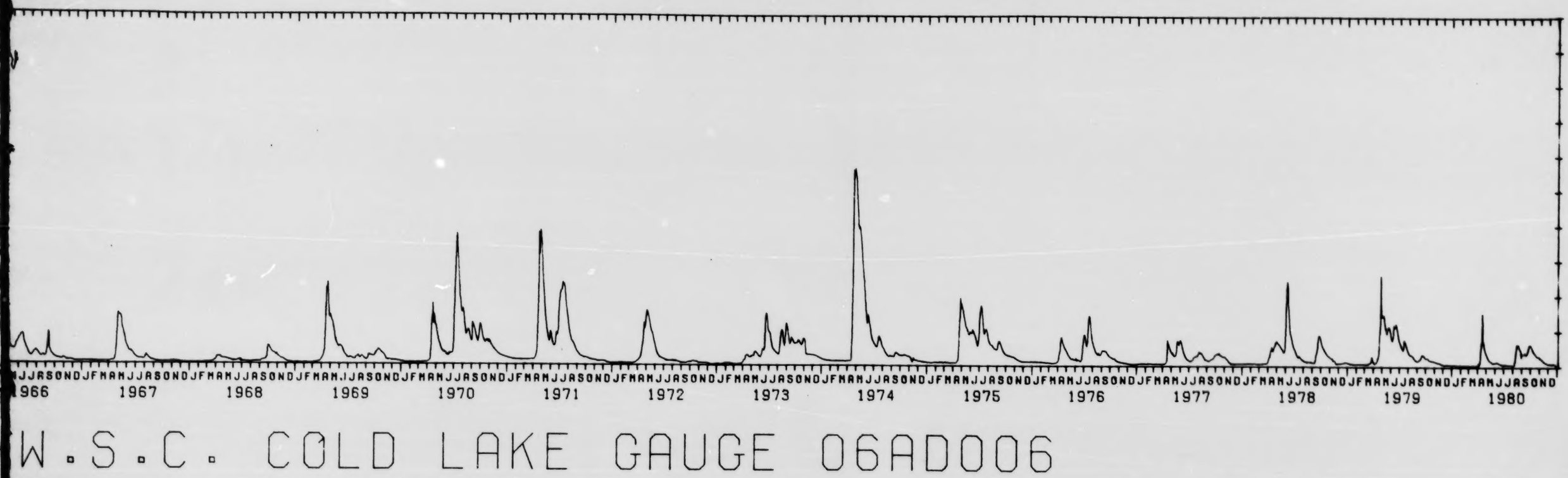
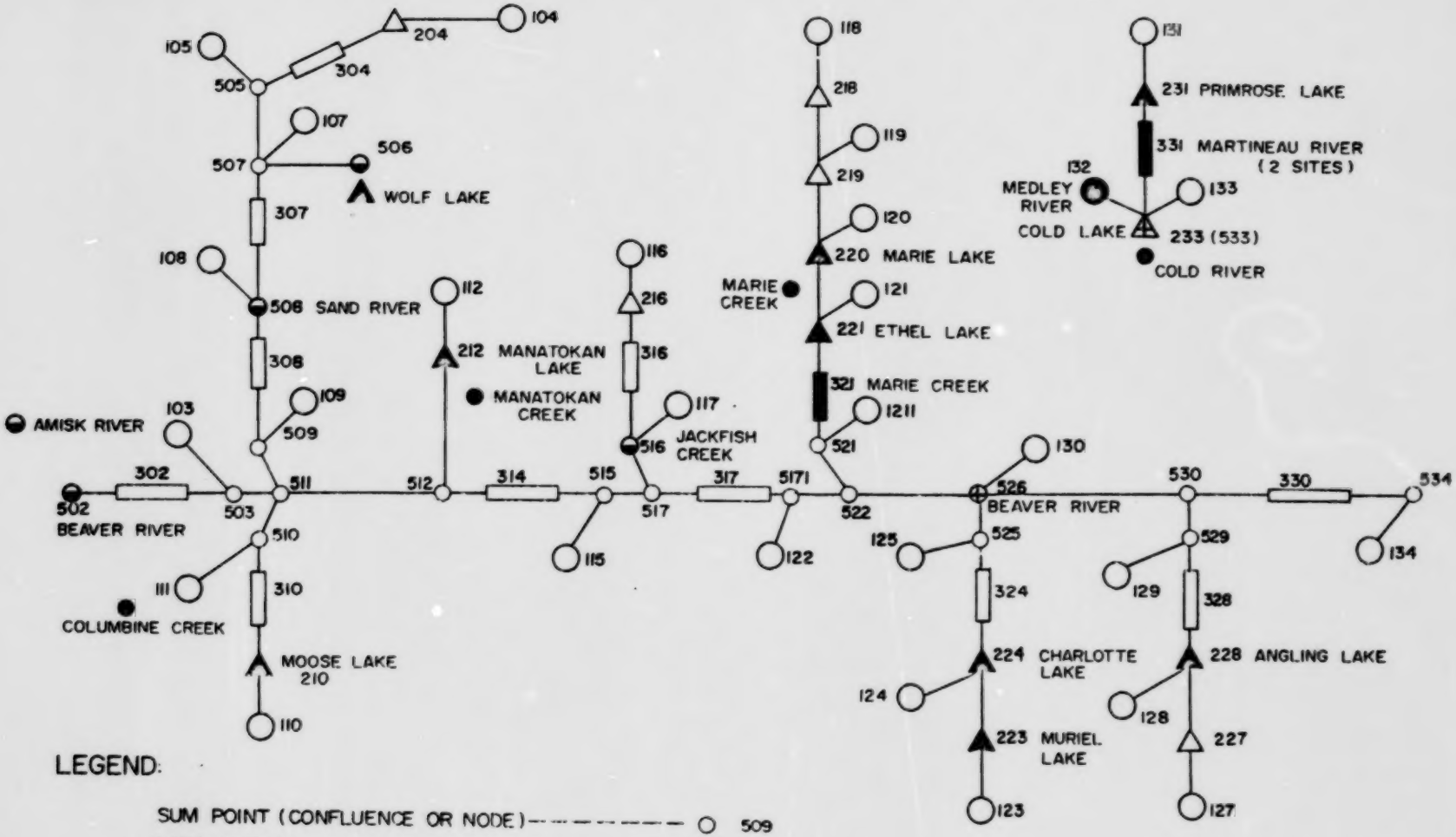


FIGURE 4

DISCHARGE HYDROGRAPH

BEAVER RIVER AT W.S.C.
COLD LAKE GAUGE
(STUDY POINT [illegible])



LEGEND:

- SUM POINT (CONFLUENCE OR NODE) ○ 509
- LOCAL INFLOW ○ 112
- LAKE △ 212
- CHANNEL ROUTING REACH ▭ 308
- FIRST-ORDER STATIONS (CONTINUOUS 1956-1980) ⊕
- SECOND-ORDER STATIONS (CONTINUOUS OR SEASONAL, SINCE 1970 !) ◒
- THIRD-ORDER STATIONS (SHORT TERM, INTERMITTENT) ●

FIGURE 7

LOCATION OF HYDROMETRIC STATIONS

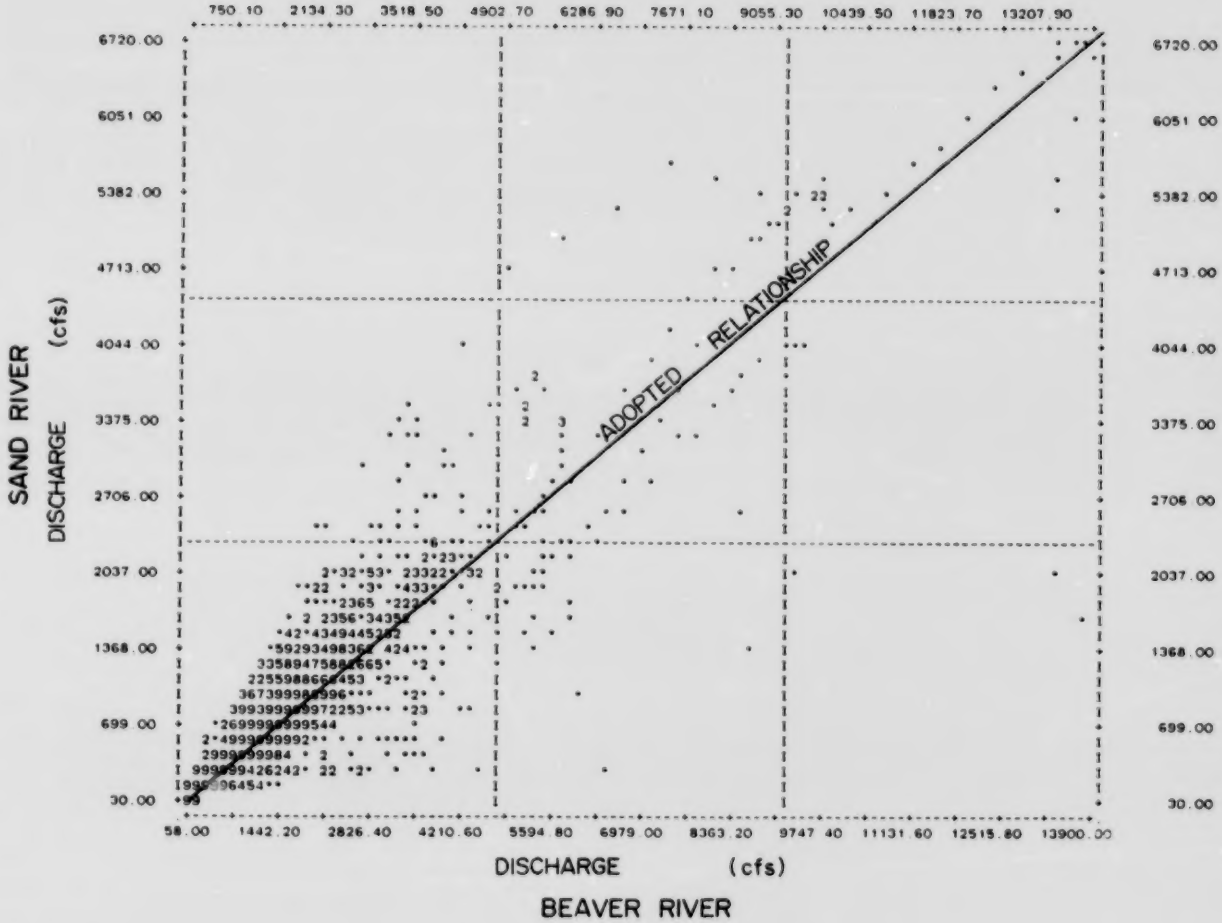
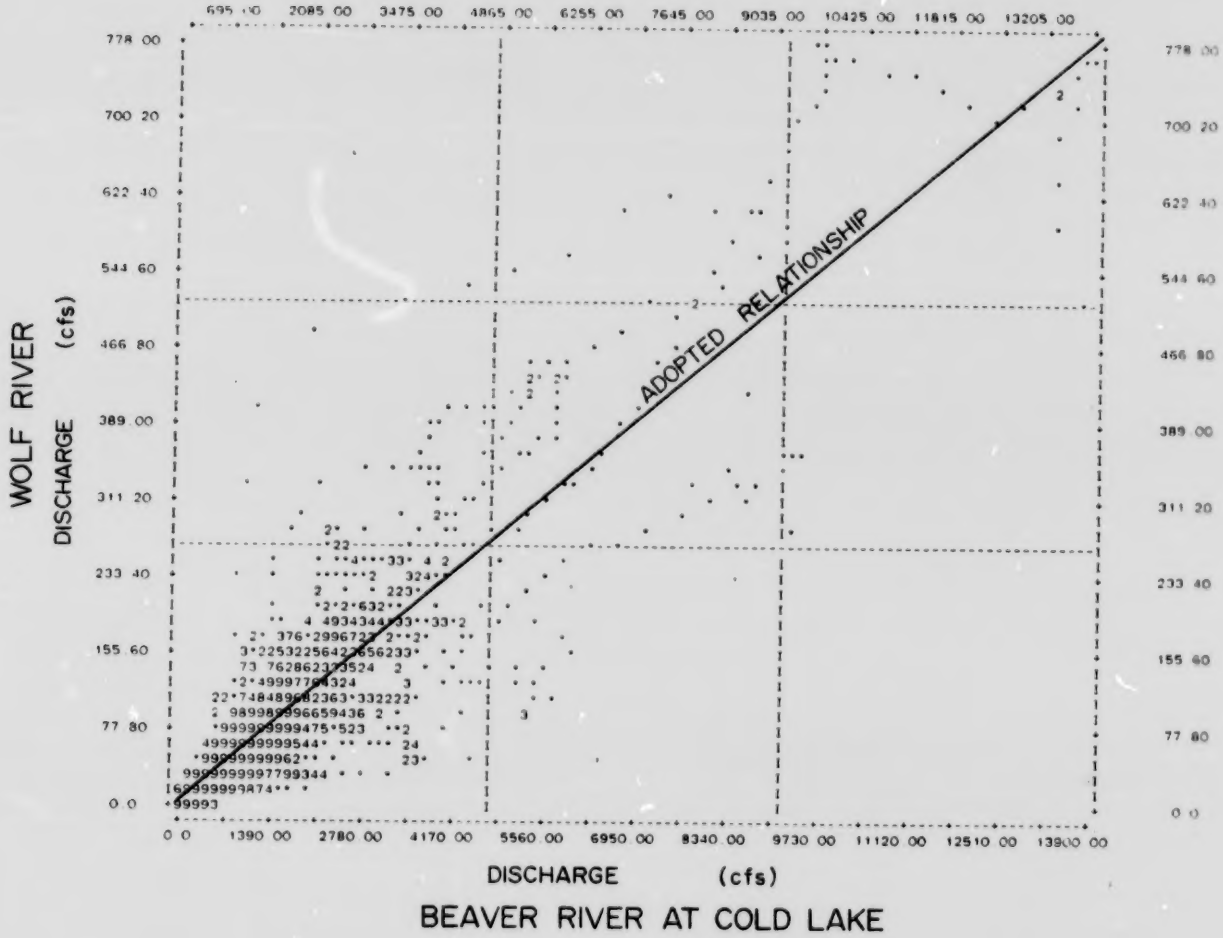


FIGURE 8

CORRELATION OF DAILY DISCHARGES

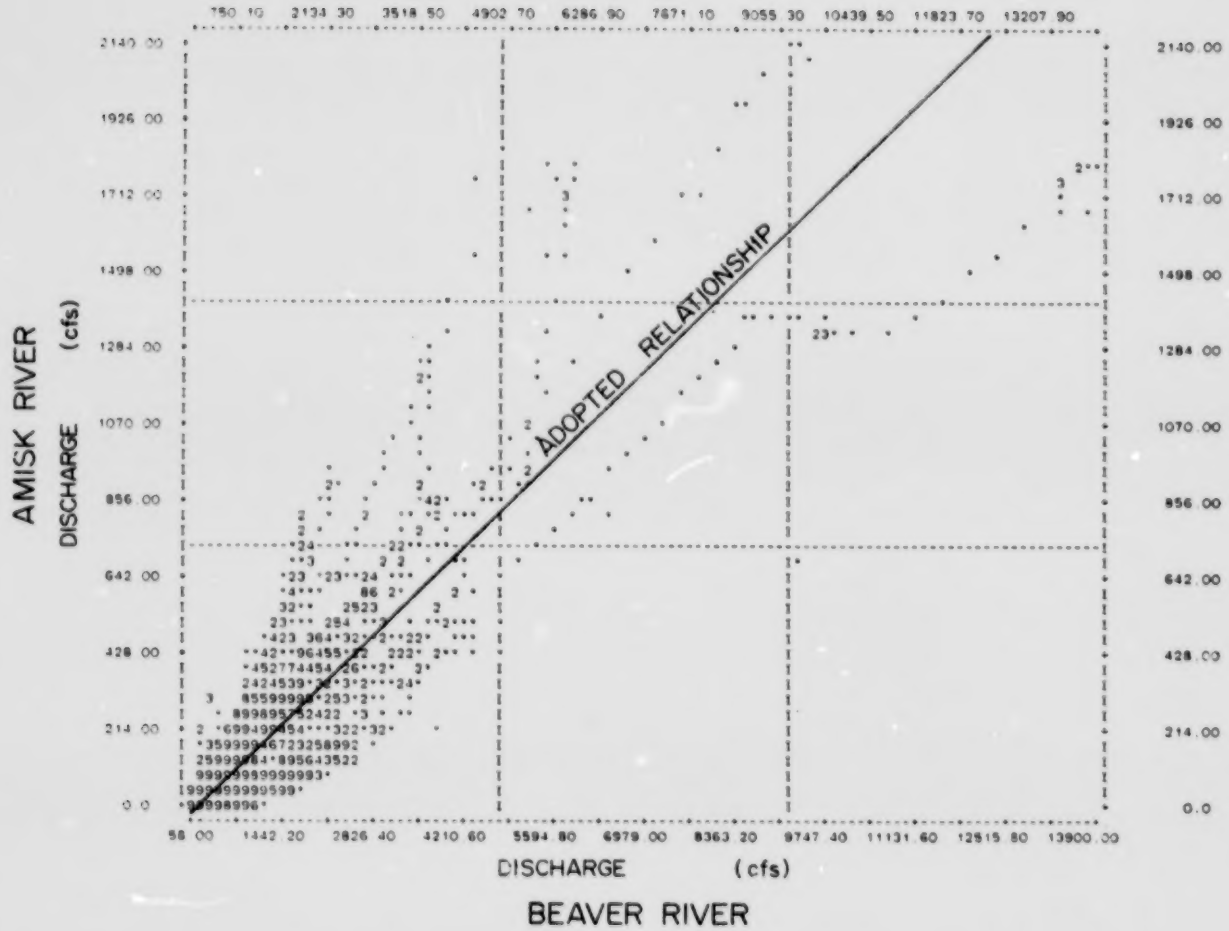
SAND RIVER vs. BEAVER RIVER



NOTE:
BEAVER RIVER DISCHARGES ARE LAGGED 5 DAYS.

FIGURE 9

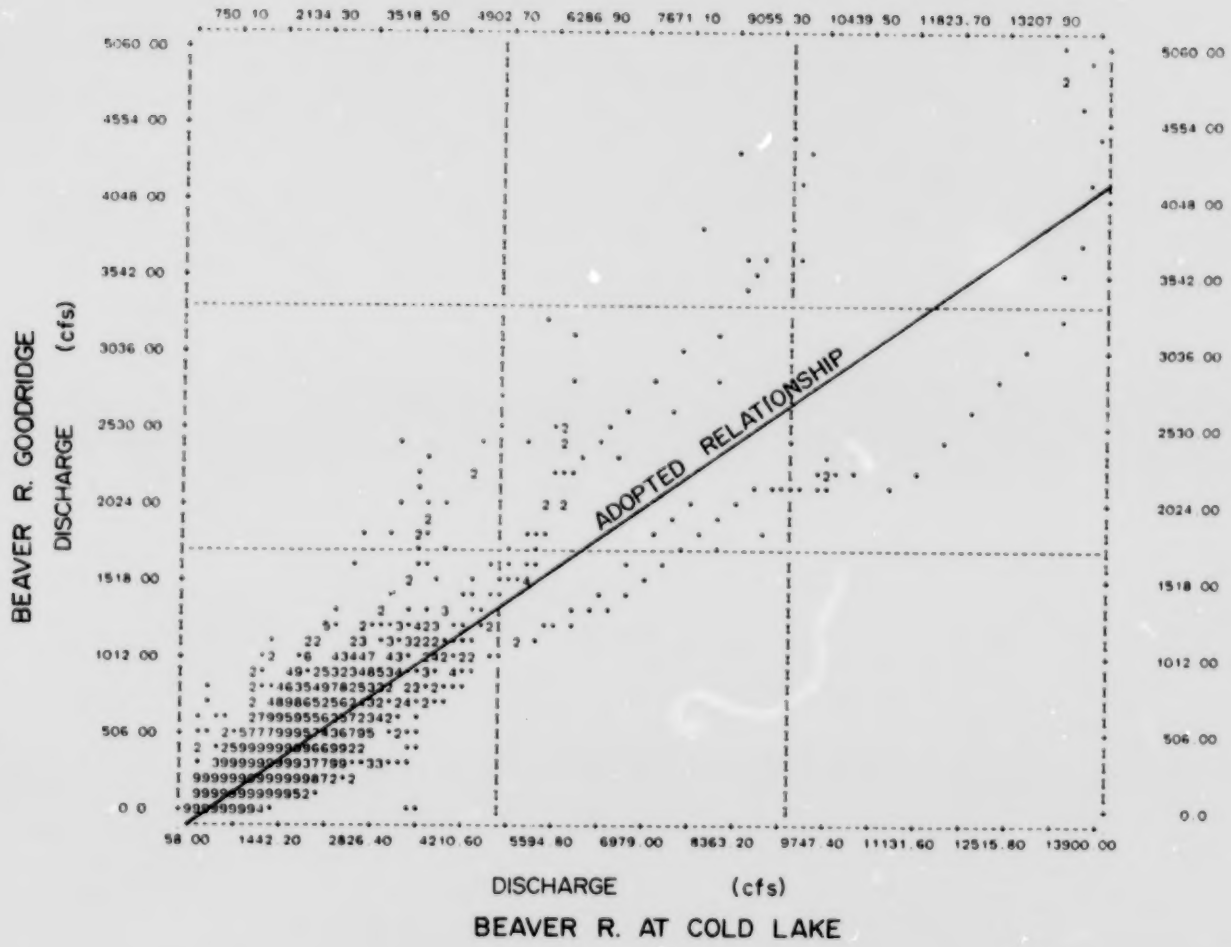
CORRELATION OF DAILY DISCHARGES
WOLF RIVER vs. BEAVER RIVER



NOTE:
AMISK RIVER DISCHARGES ARE LAGGED 2 DAYS.

FIGURE 10

CORRELATION OF DAILY DISCHARGES
AMISK RIVER vs. BEAVER RIVER



NOTE: BEAVER RIVER AT GOODRIDGE DISCHARGES ARE LAGGED 2 DAYS.

FIGURE 11

CORRELATION OF DAILY DISCHARGES

BEAVER R. (GOODRIDGE) vs. BEAVER R. (COLD LAKE)

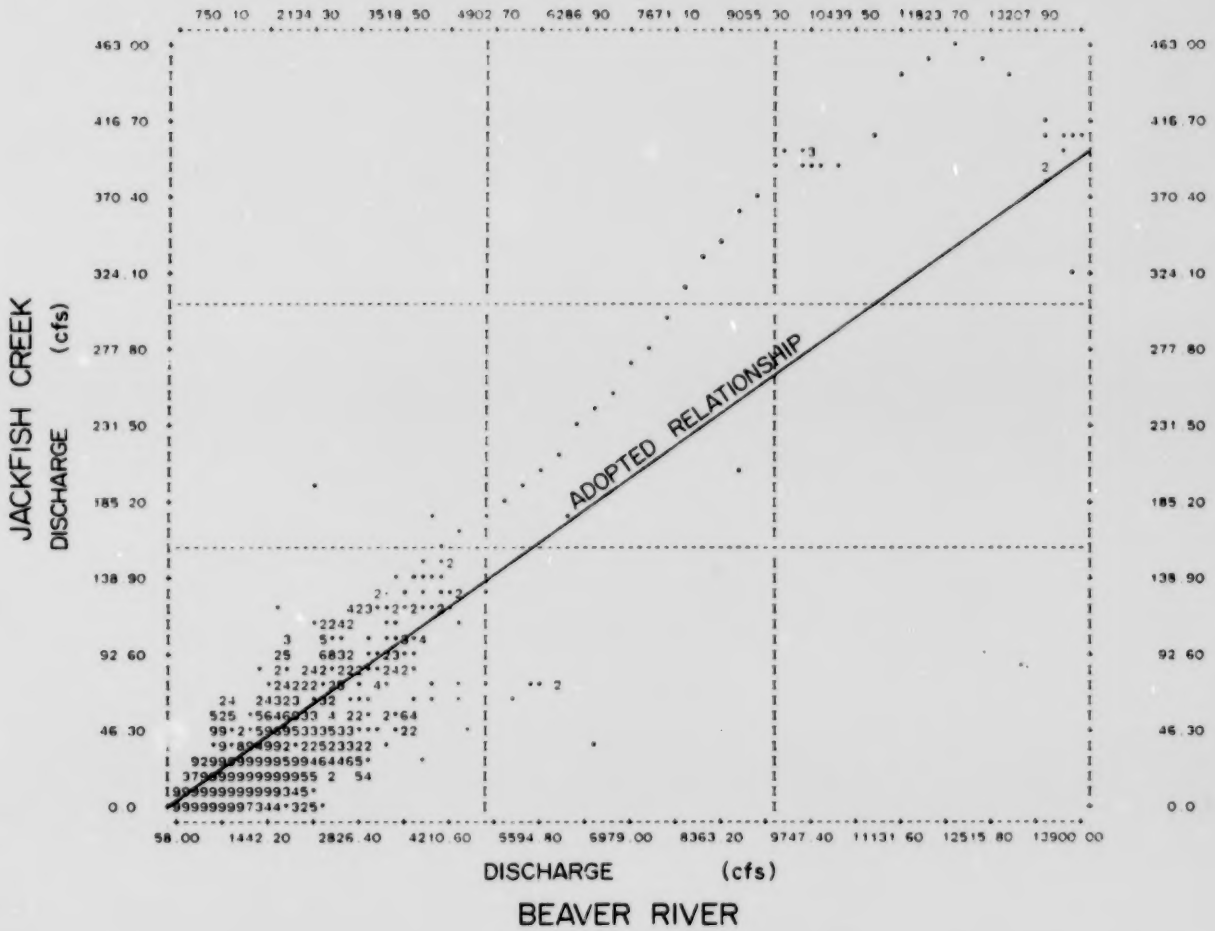
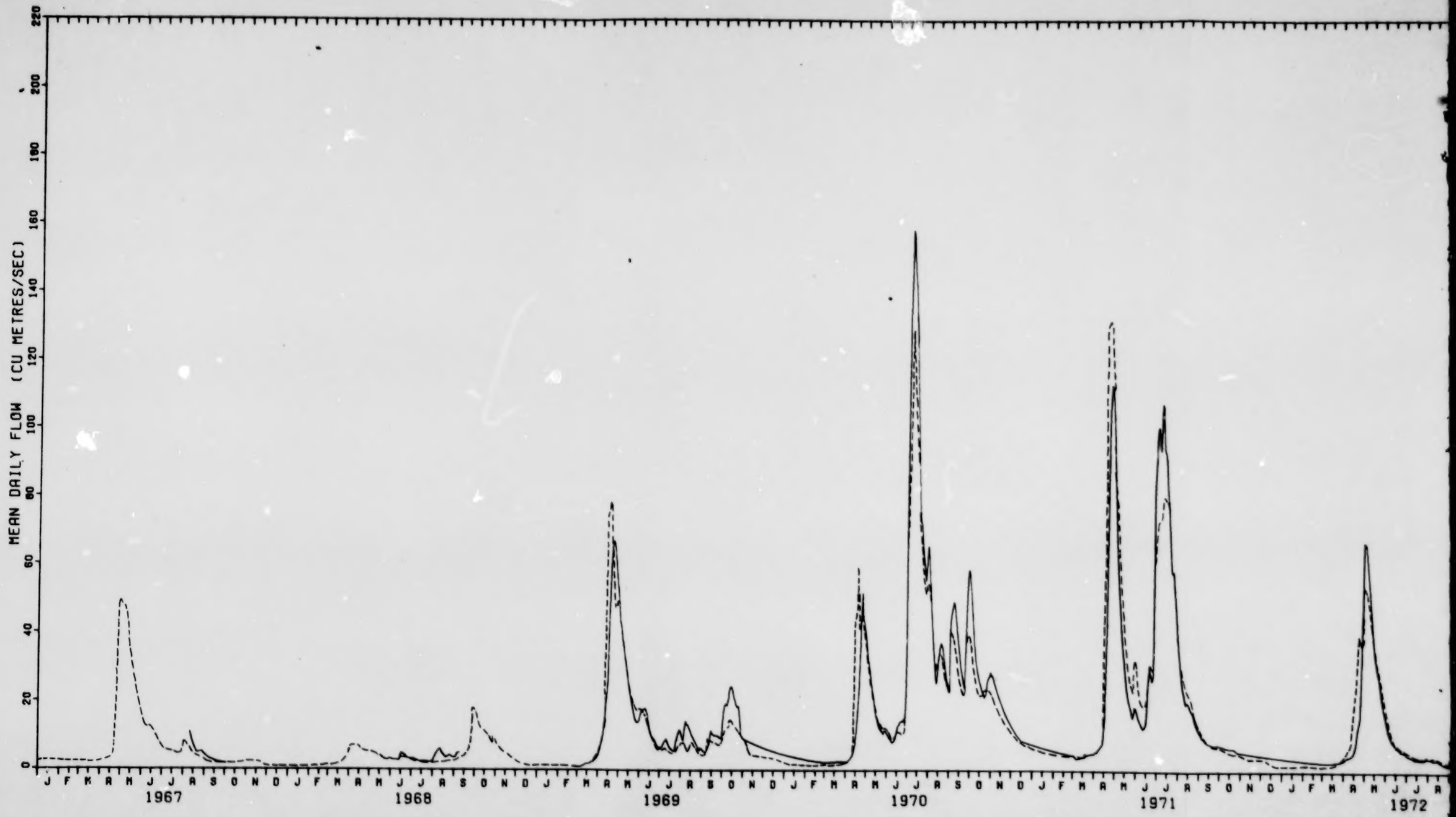
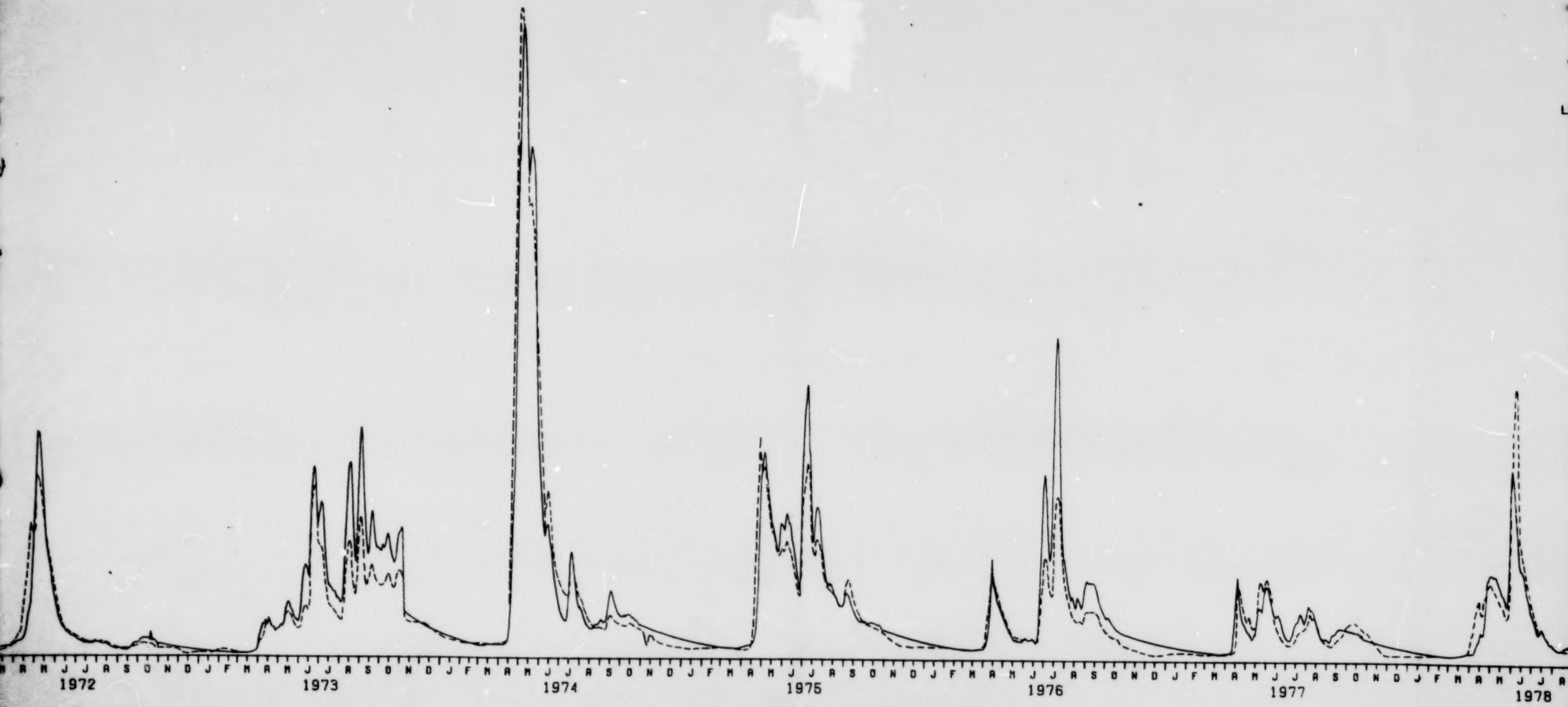


FIGURE 12

CORRELATION OF DAILY DISCHARGES

JACKFISH CREEK vs. BEAVER RIVER


MEAN DAILY FLOW (CU METRES/SEC)
0
20
40
60
80
100
120
140
160
180
200
220
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A
1967
1968
1969
1970
1971
1972


1972
1973
1974
1975
1976
1977
1978

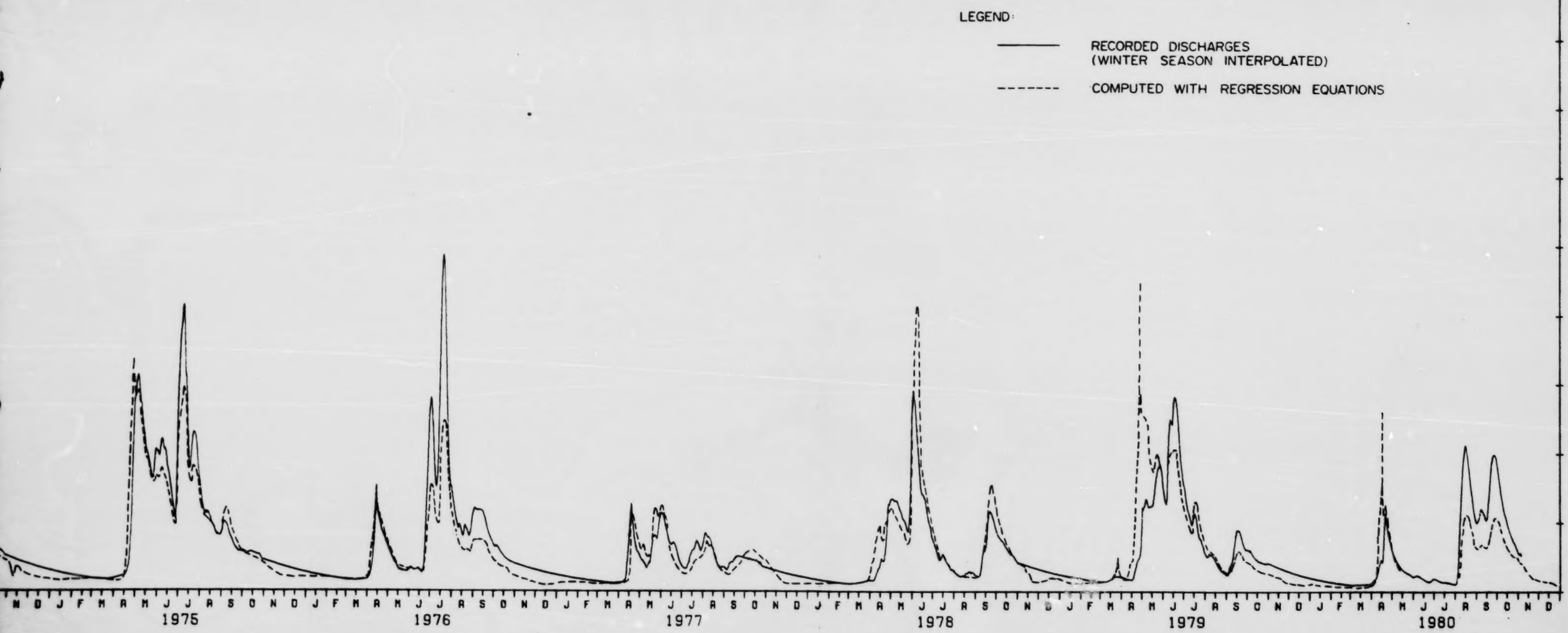
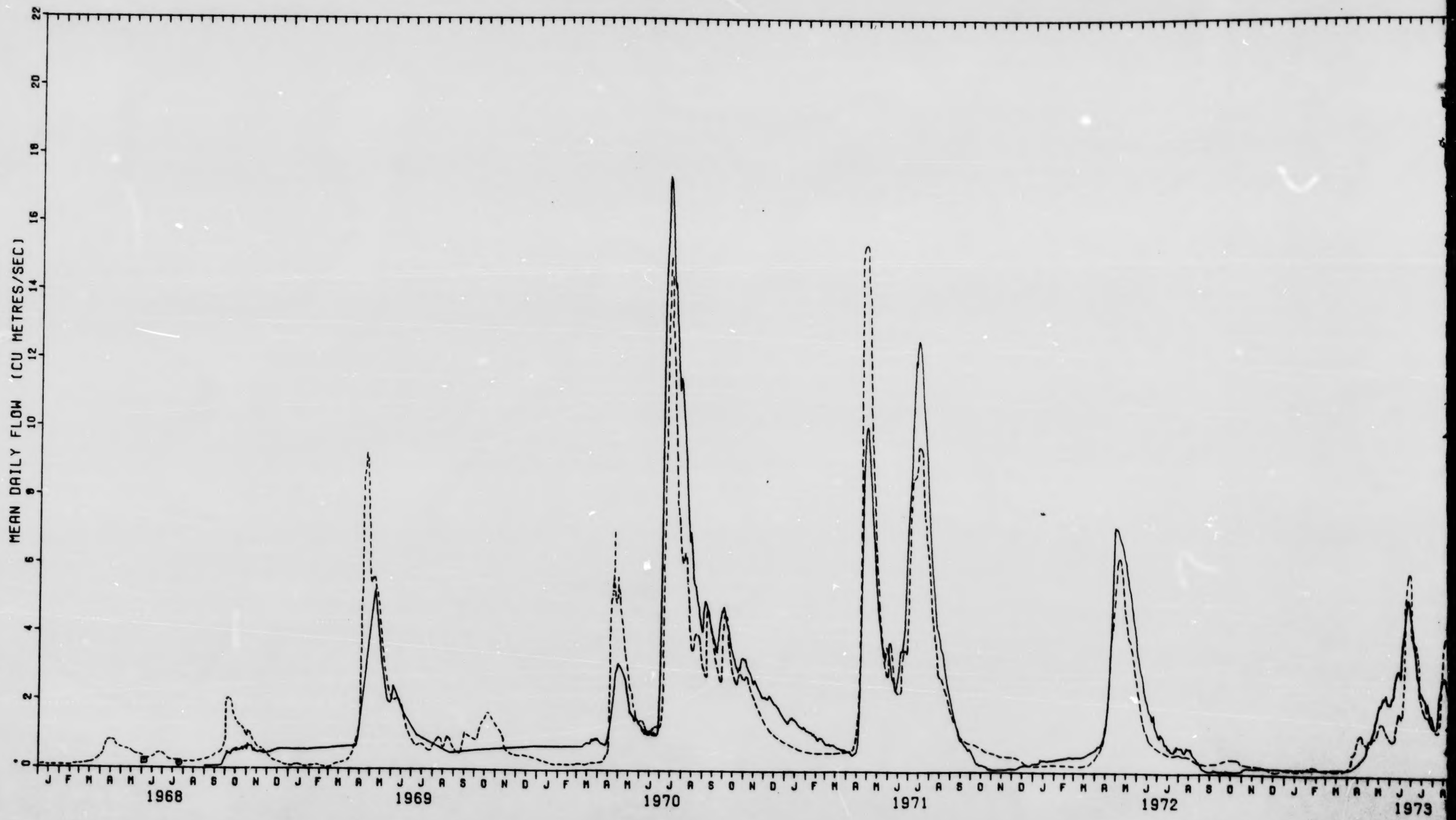
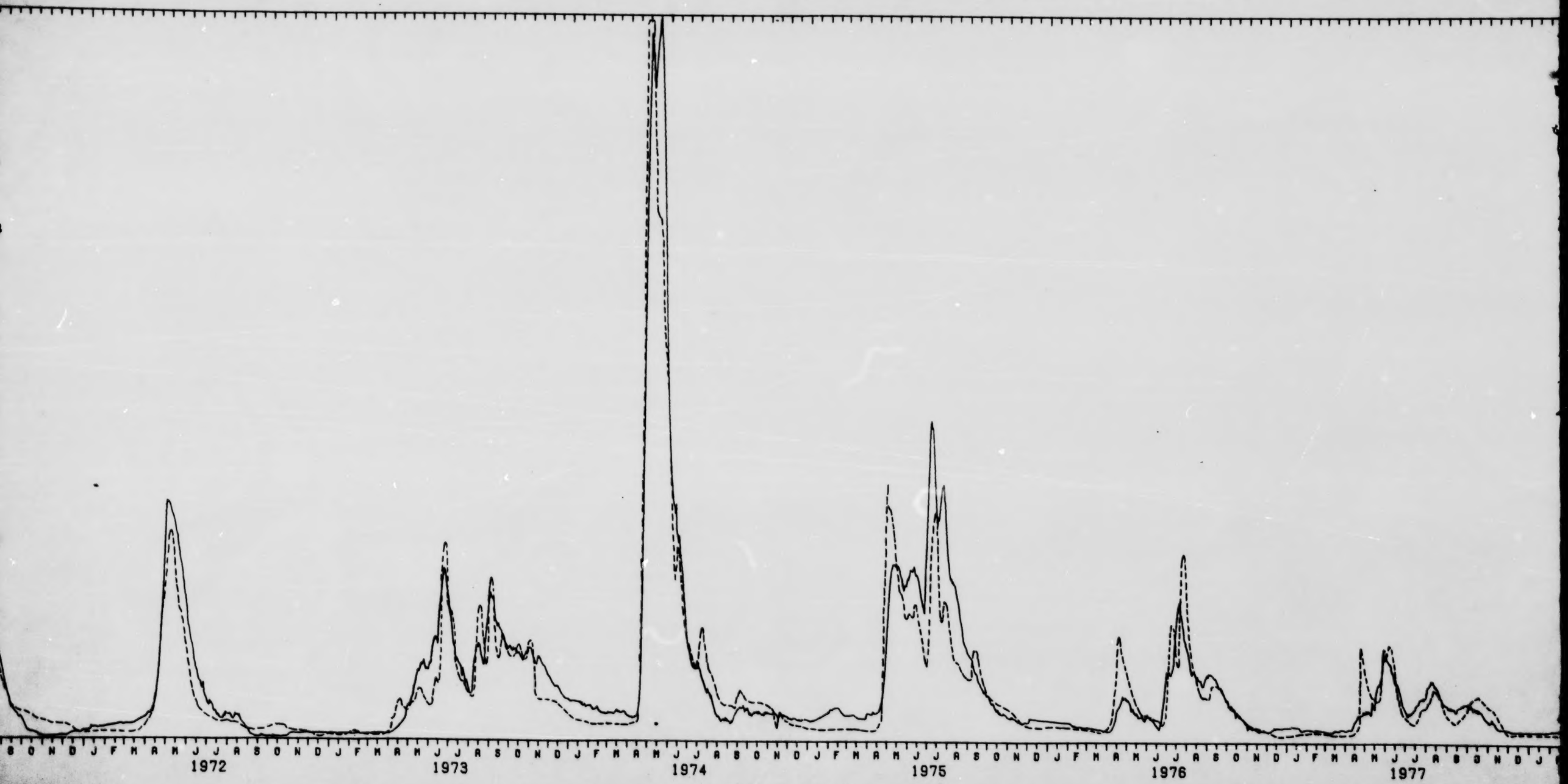


FIGURE 13

COMPARISON OF RECORDED DISCHARGES WITH RESULTS OF REGRESSION ANALYSIS

SAND RIVER


MEAN DAILY FLOW (CU METRES/SEC)
0
2
4
6
8
10
12
14
16
18
20
22
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A
1968
1969
1970
1971
1972
1973


1972
1973
1974
1975
1976
1977

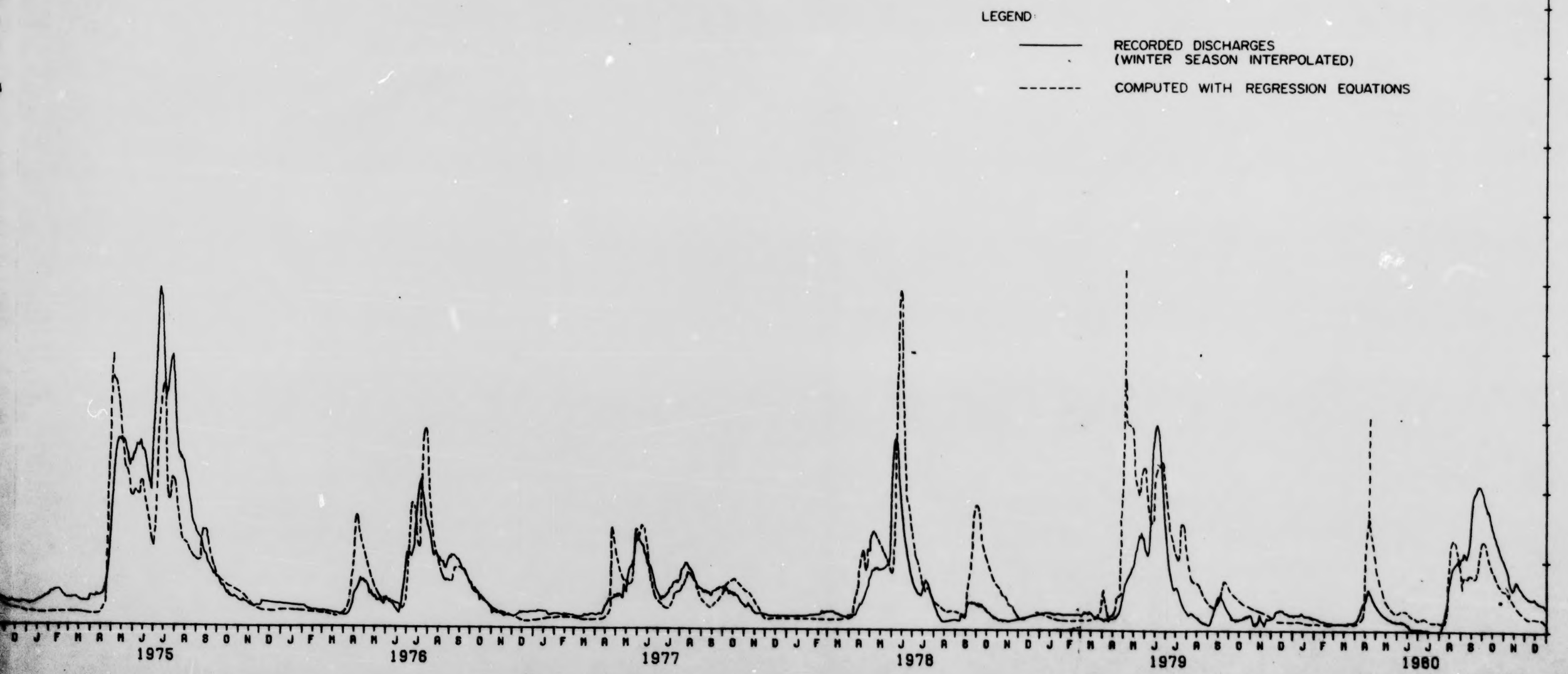
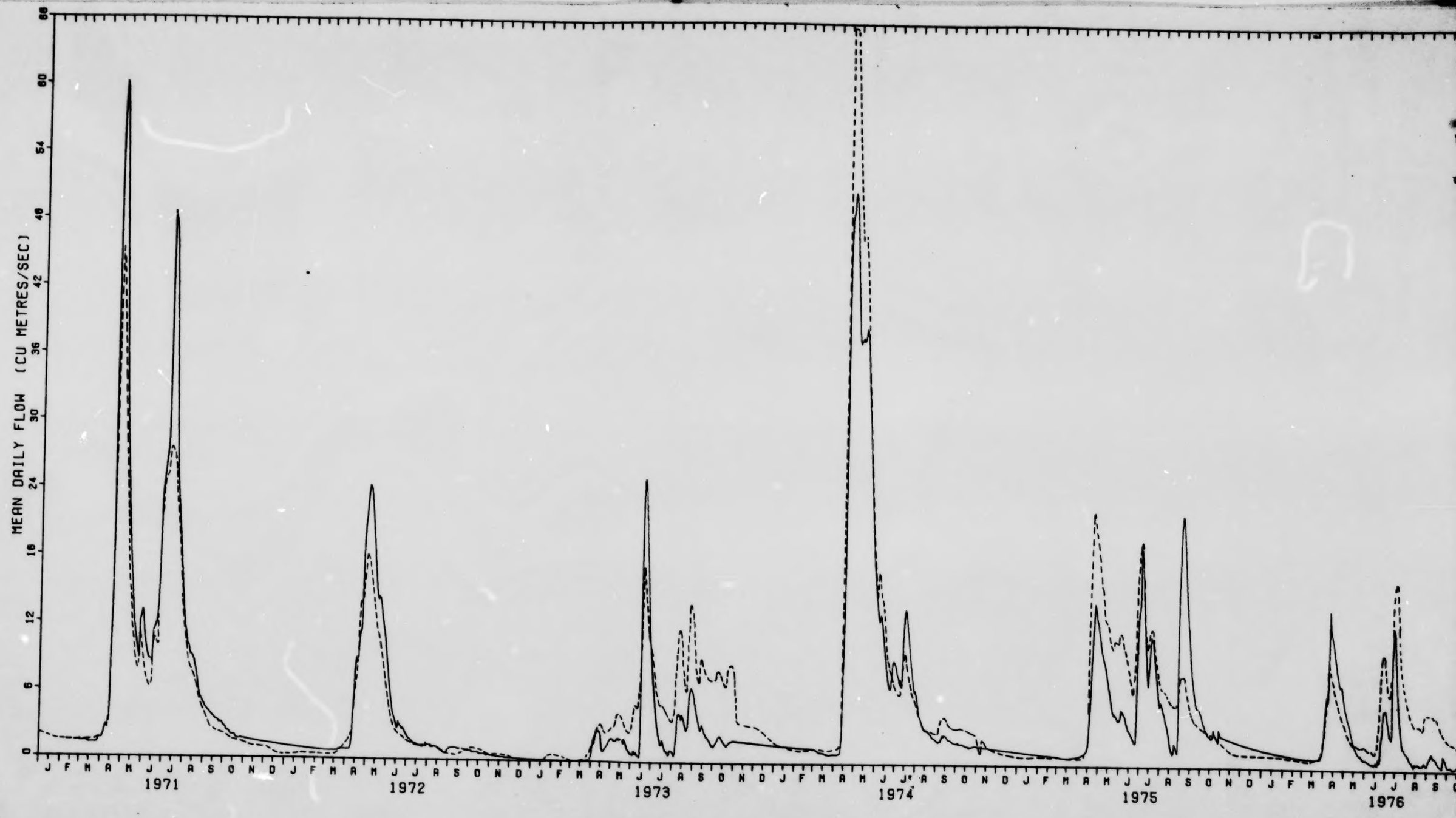


FIGURE 14
COMPARISON OF RECORDED DISCHARGES
WITH RESULTS OF REGRESSION ANALYSIS
WOLF RIVER


MEAN DAILY FLOW (CU METRES/SEC)
0
6
12
18
24
30
36
42
48
54
60
66
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O
1971
1972
1973
1974
1975
1976

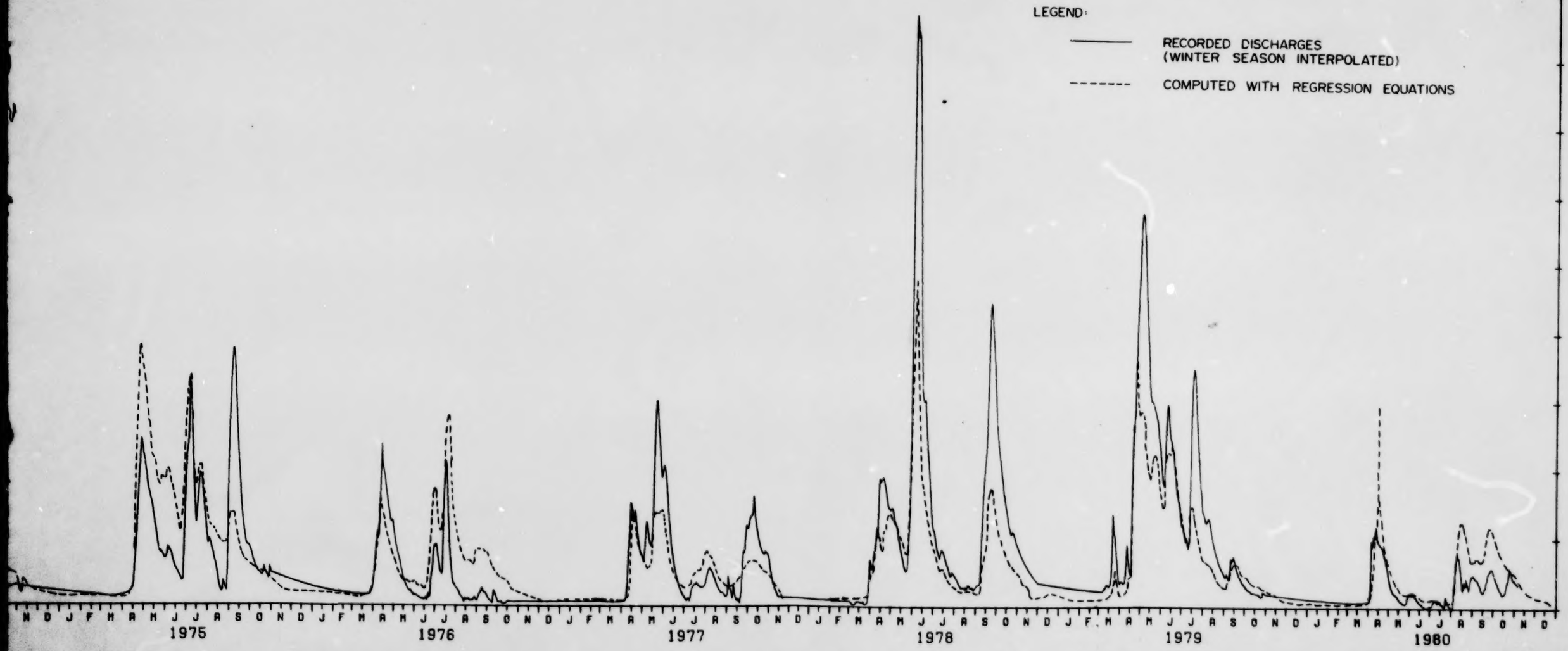
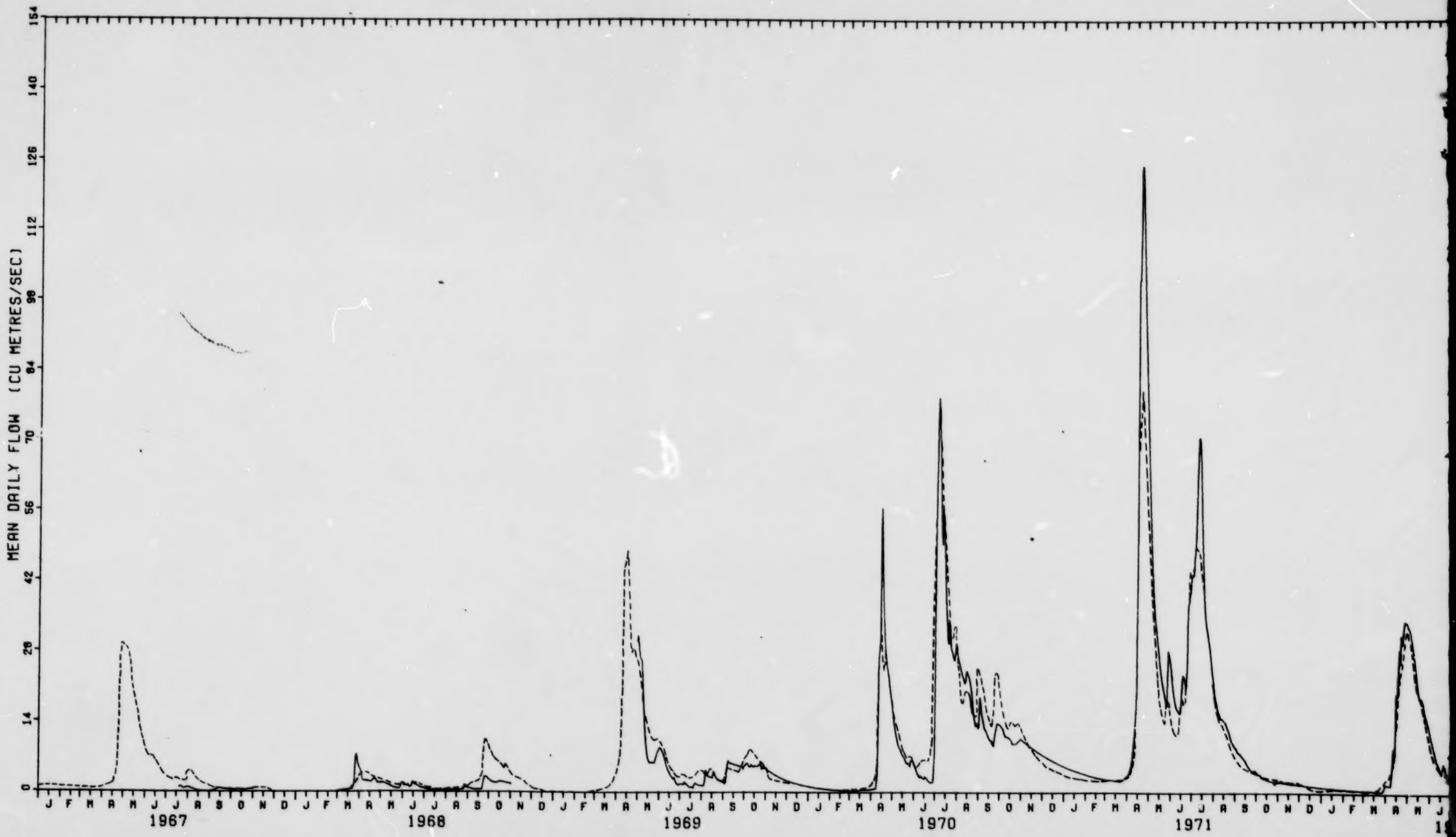
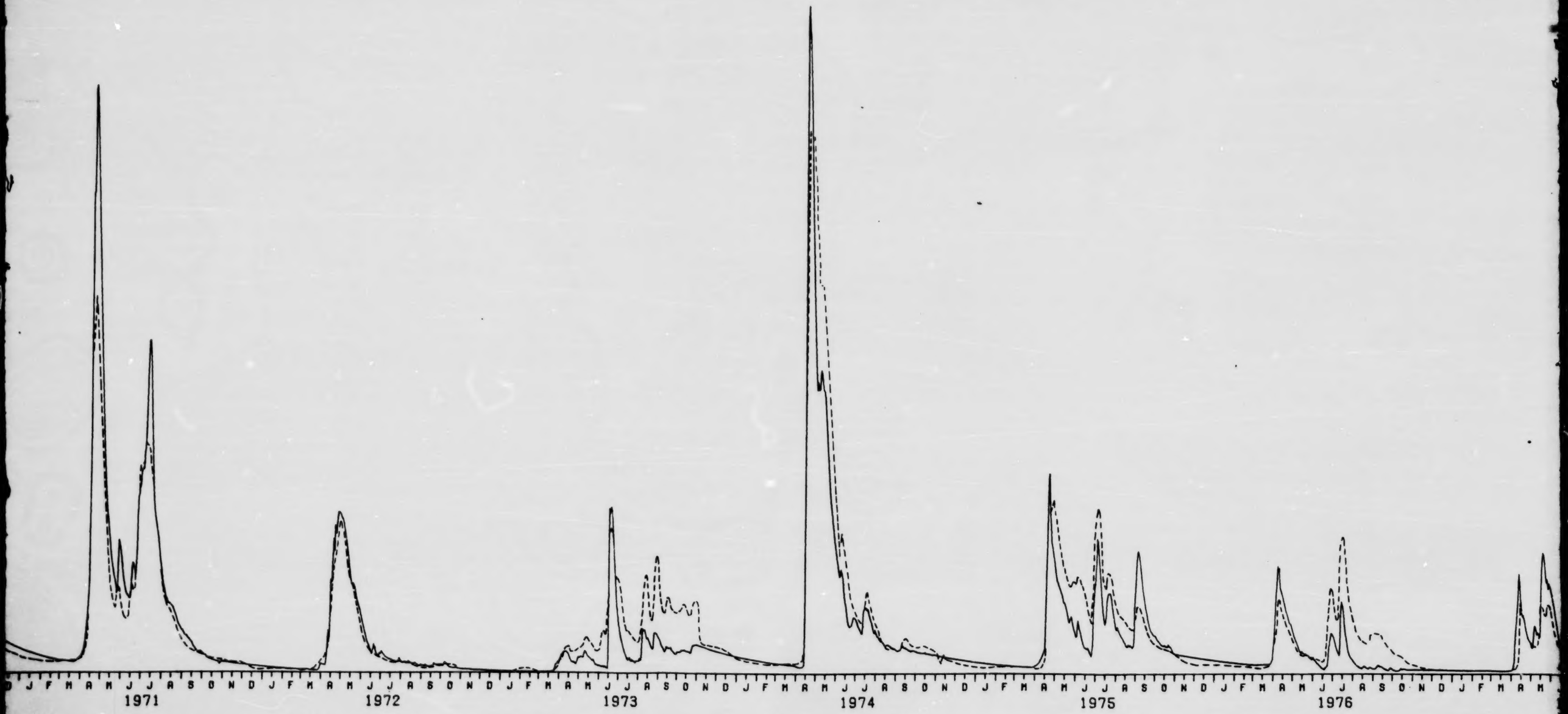


FIGURE 15

COMPARISON OF RECORDED DISCHARGES WITH RESULTS OF REGRESSION ANALYSIS

AMISK RIVER


MEAN DAILY FLOW (CU METRES/SEC)
0
14
28
42
56
70
84
98
112
126
140
154
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J
1967
1968
1969
1970
1971


1971
1972
1973
1974
1975
1976

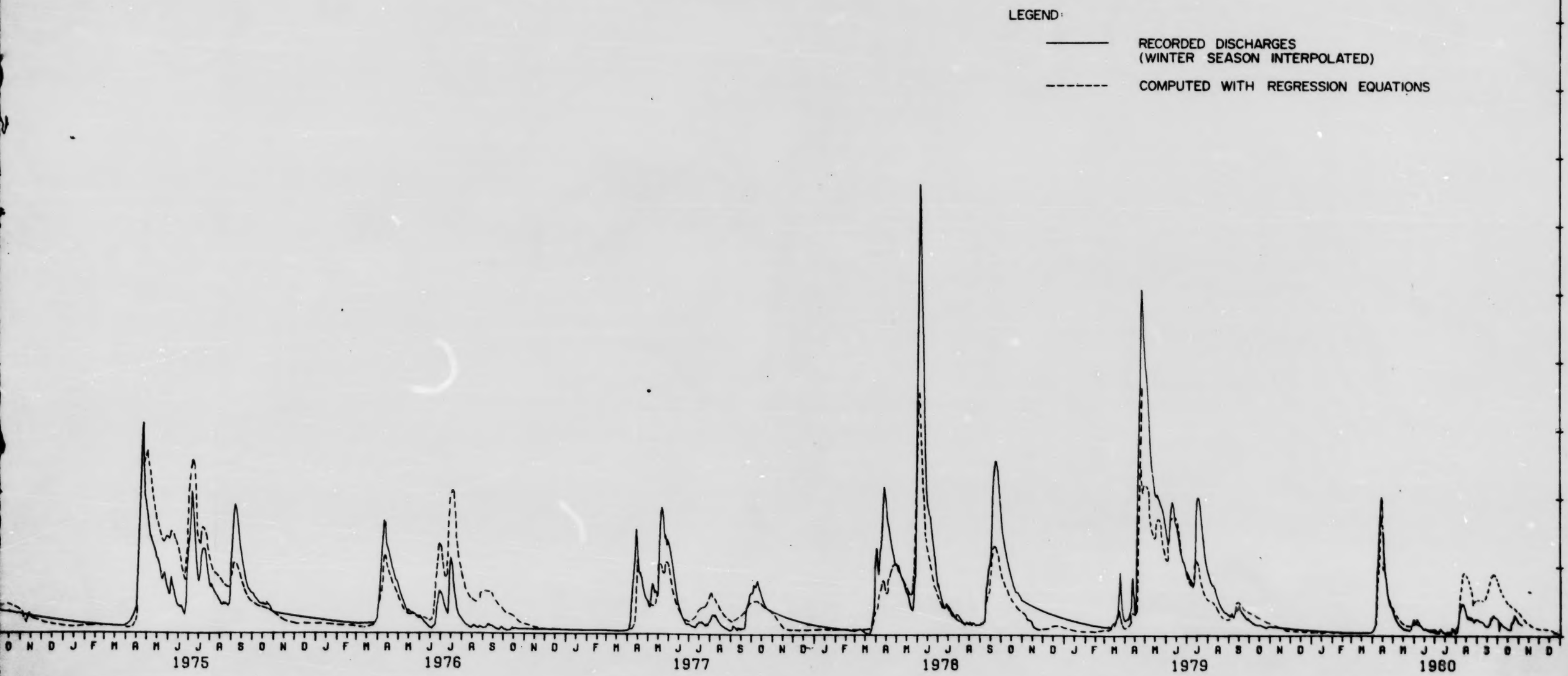
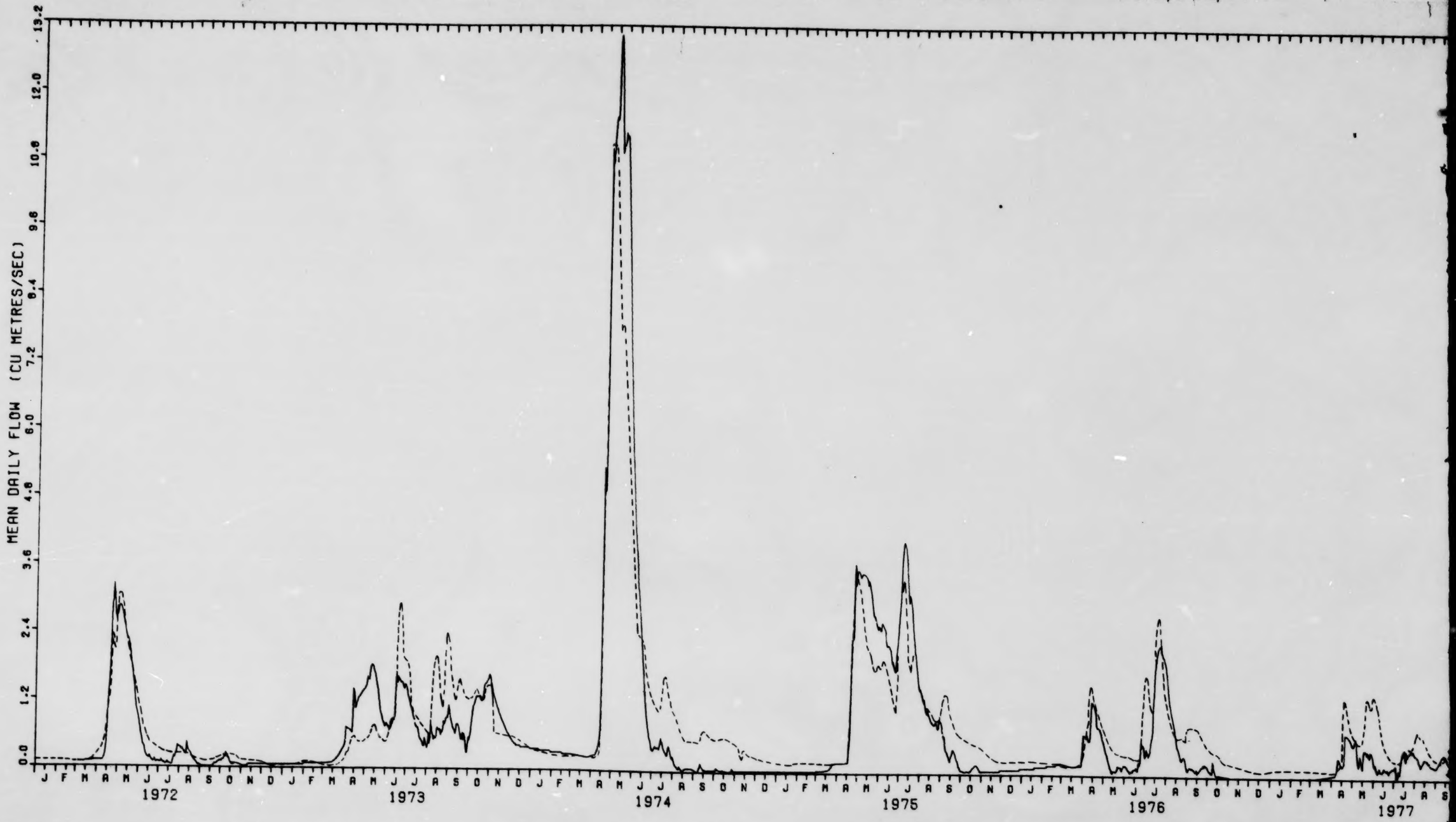


FIGURE 16

COMPARISON OF RECORDED DISCHARGES WITH RESULTS OF REGRESSION ANALYSIS

BEAVER RIVER AT GOODRIDGE


MEAN DAILY FLOW (CU METRES/SEC)
0.0
1.2
2.4
3.6
4.8
6.0
7.2
8.4
9.6
10.8
12.0
13.2
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S
1972
1973
1974
1975
1976
1977

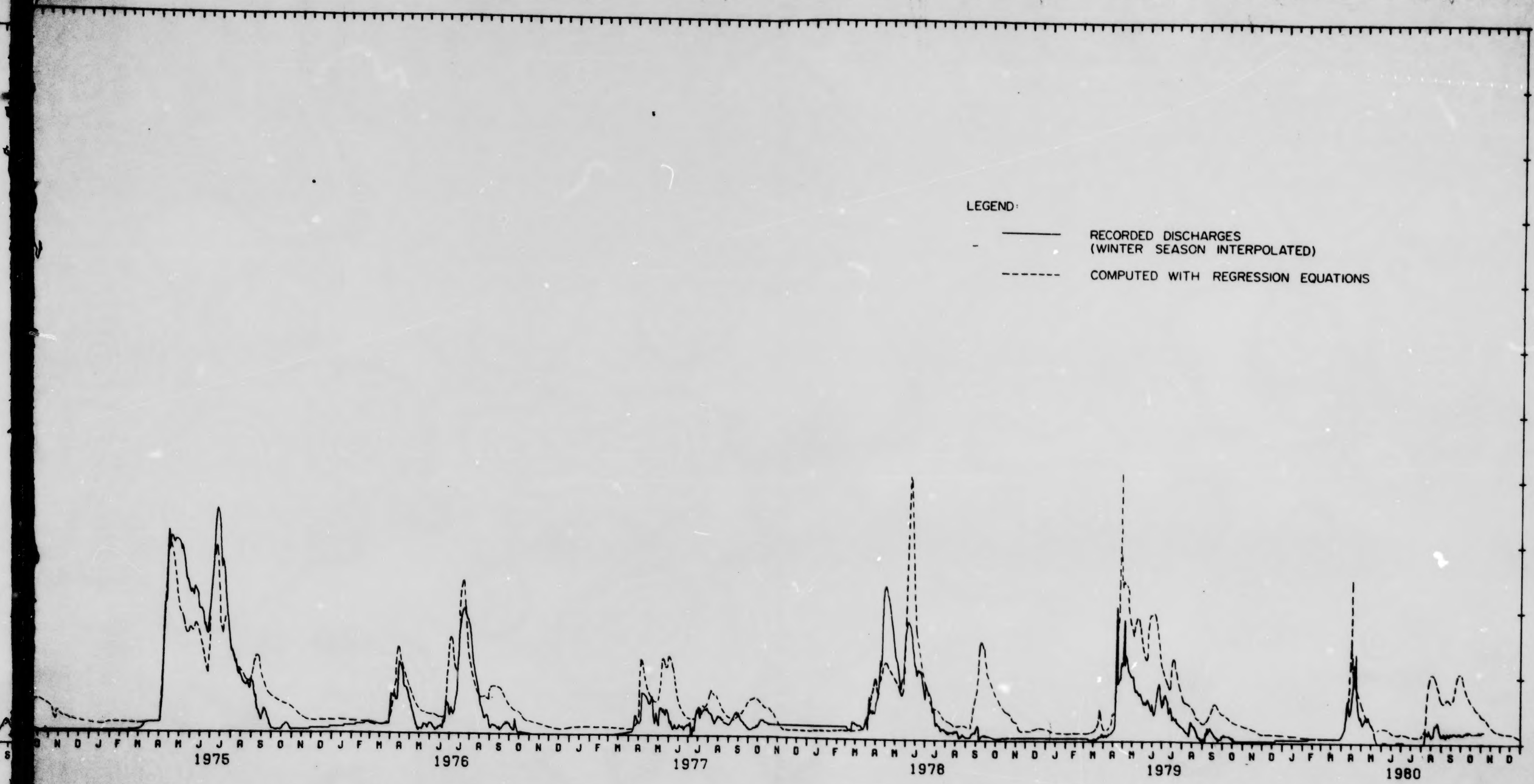
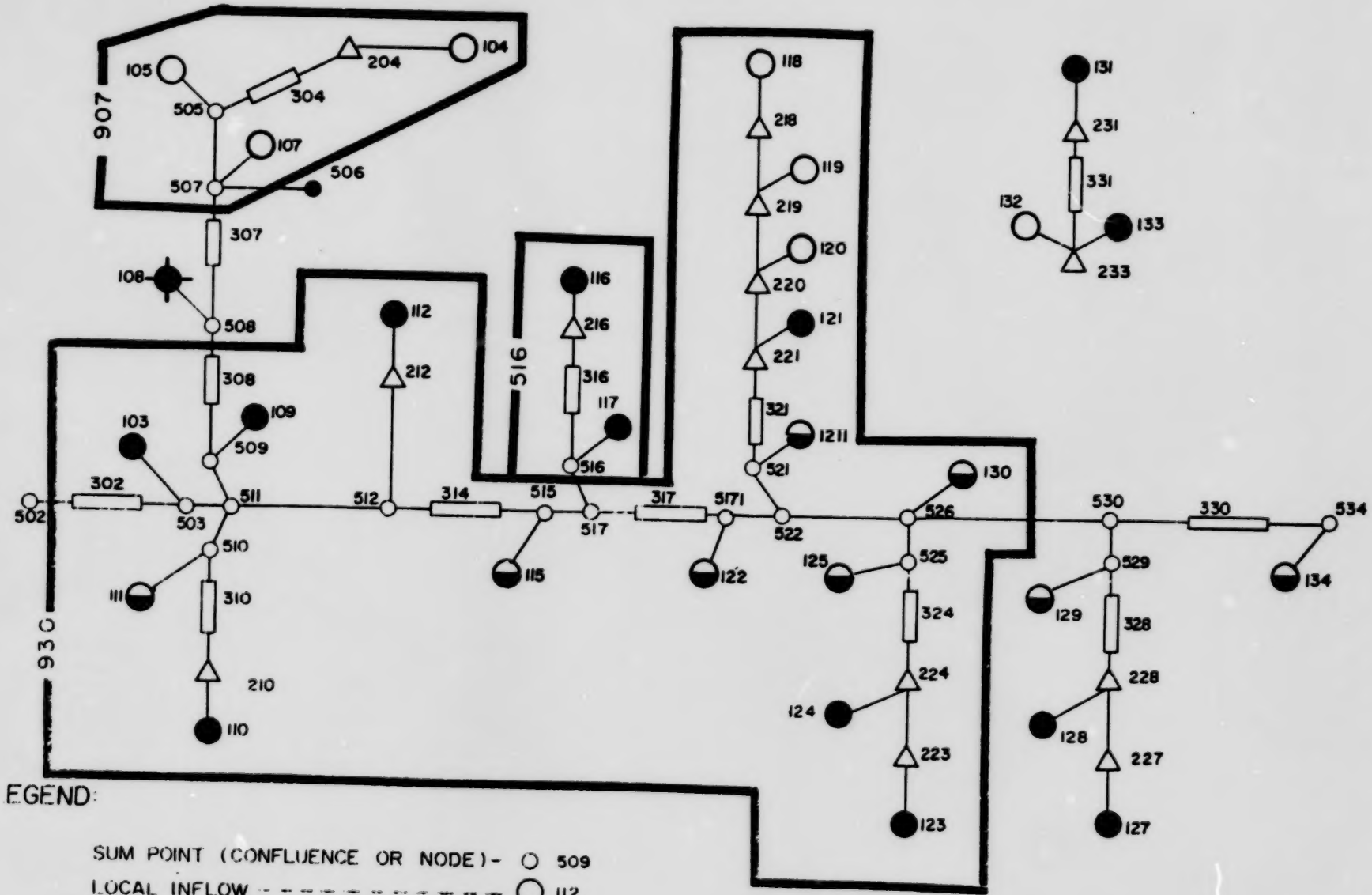


FIGURE 17
COMPARISON OF RECORDED DISCHARGES
WITH RESULTS OF REGRESSION ANALYSIS
JACKFISH CREEK



EGEND:

SUM POINT (CONFLUENCE OR NODE) - ○ 509

LOCAL INFLOW - - - - - - - - - - - - - ○ 112

LAKE - - - - - - - - - - - - - - - - - - △ 212

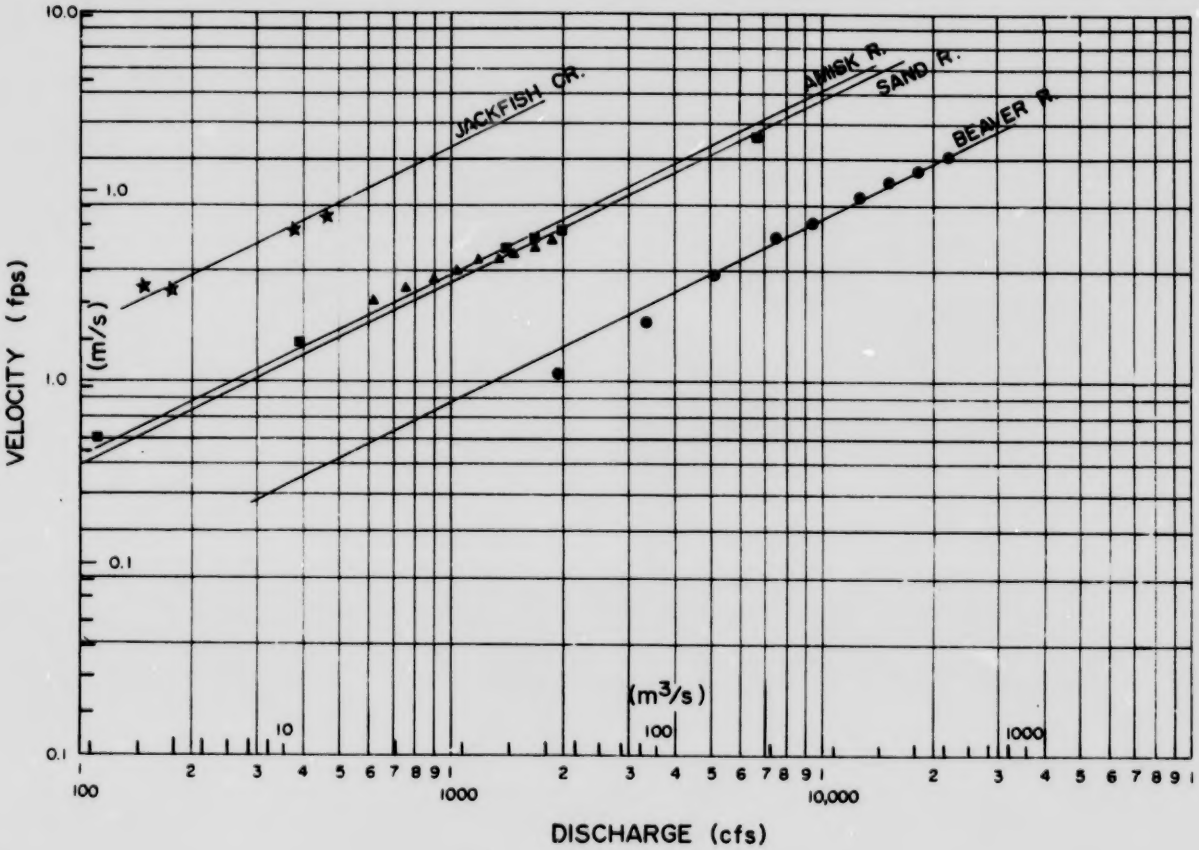
CHANNEL ROUTING REACH - - - - - - - - ▭ 308

SUB-BASIN BOUNDARY - - - - - - - - - ▬

NOTE COLOURED CIRCLES DESIGNATE LOCAL DRAINAGE AREAS OF COMPARABLE RUNOFF CHARACTERISTICS

FIGURE 18

CLASSIFICATION OF LOCAL DRAINAGE AREAS



LEGEND:

- JACKFISH CREEK
  $V = 0.136\,Q^{0.50}$
- AMISK RIVER
  $V = 0.062\,Q^{0.50}$
- SAND RIVER
  $V = 0.059\,Q^{0.50}$
- BEAVER RIVER & COLD LAKE
  $V = 0.028\,Q^{0.50}$

NOTE:

EQUATIONS ARE GIVEN IN IMPERIAL UNITS.

FIGURE 19

RELATIONSHIP OF MEAN FLOW VELOCITY TO DISCHARGE

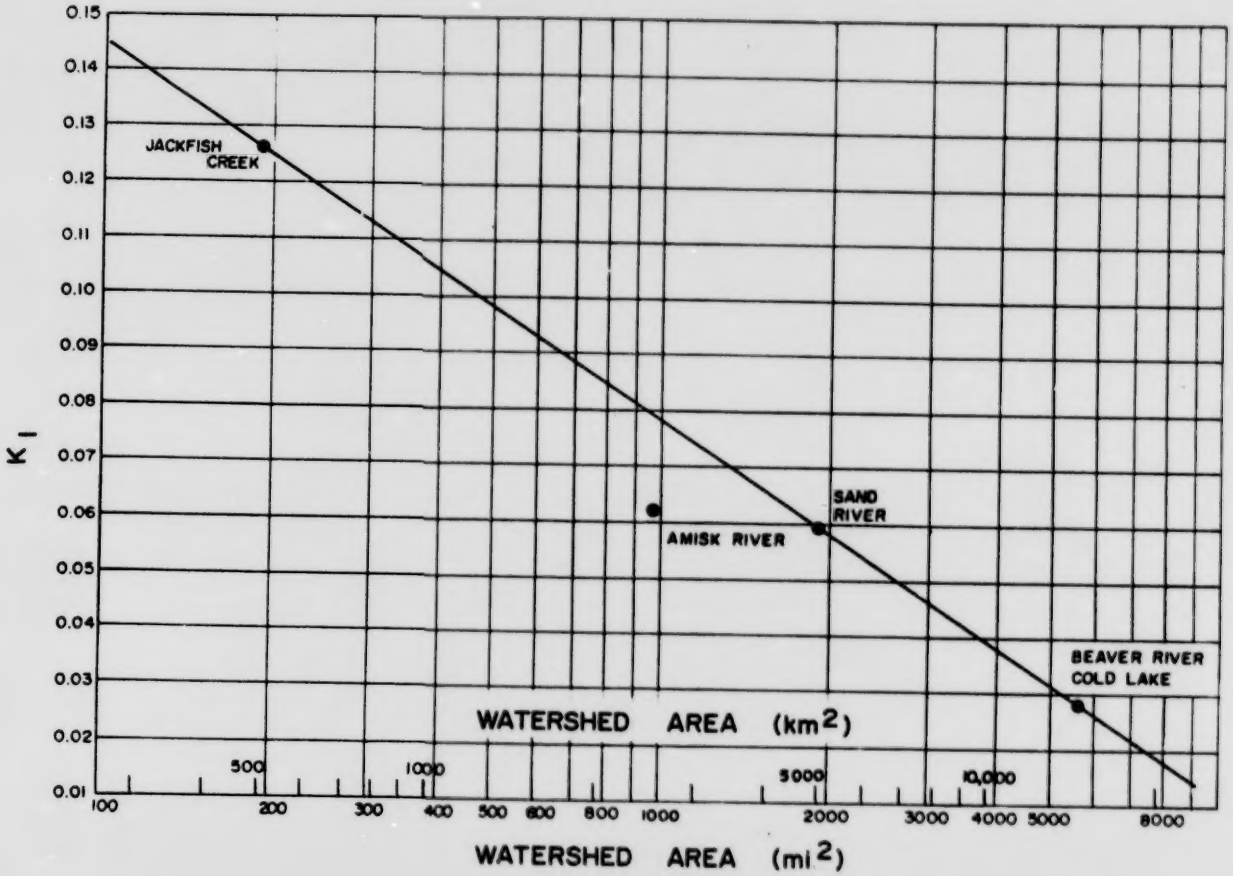
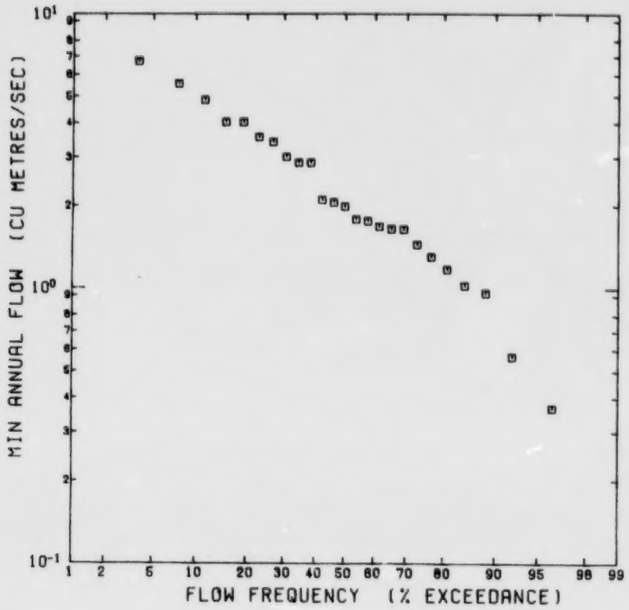
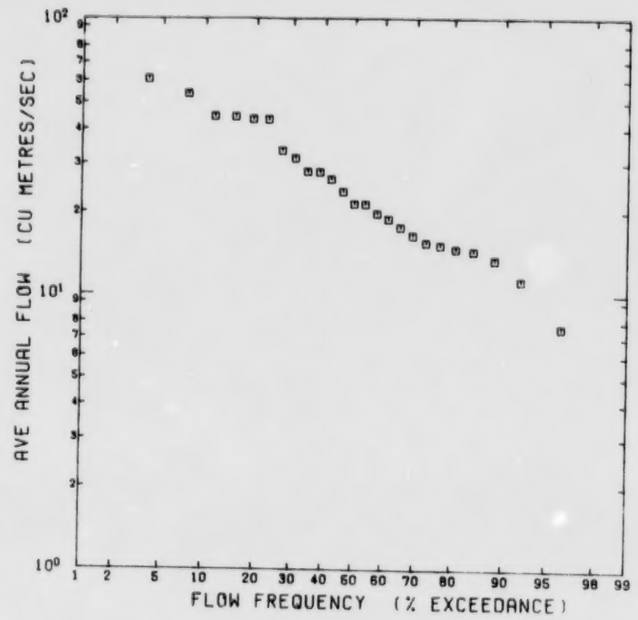
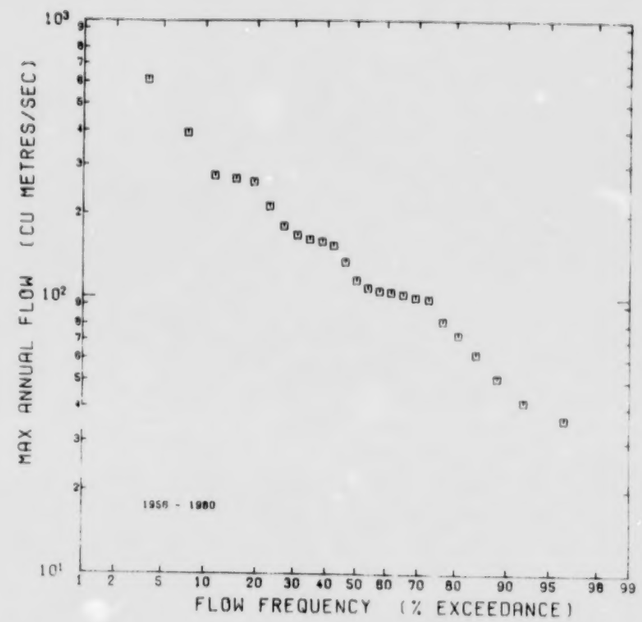


FIGURE 20

K_1 vs. WATERSHED AREA







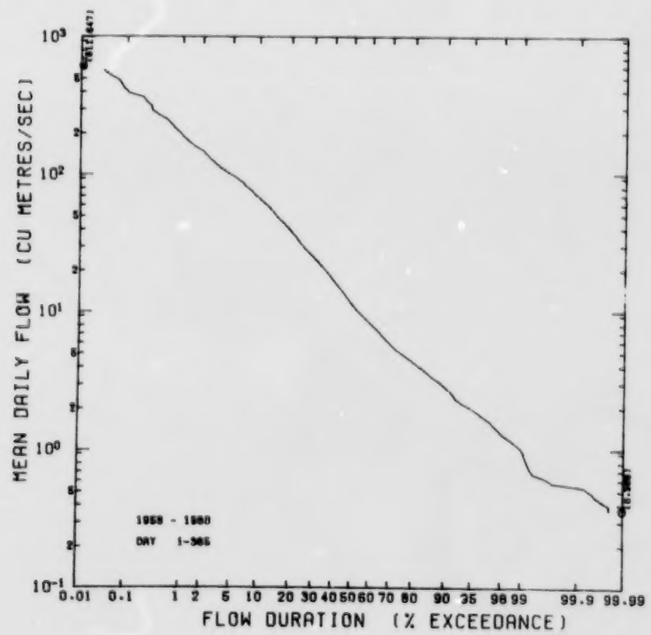
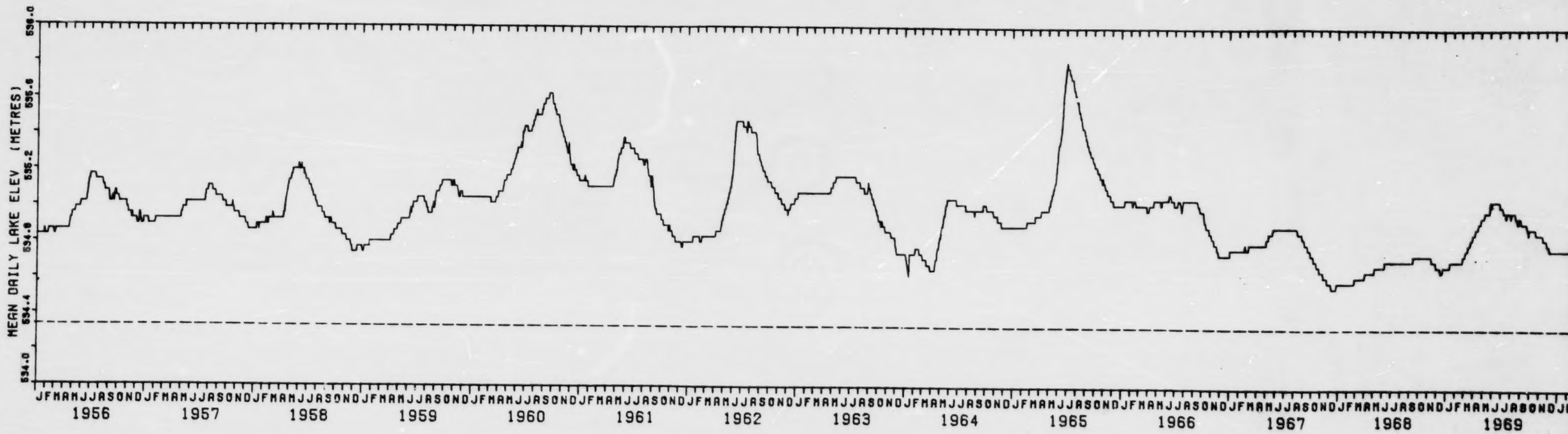


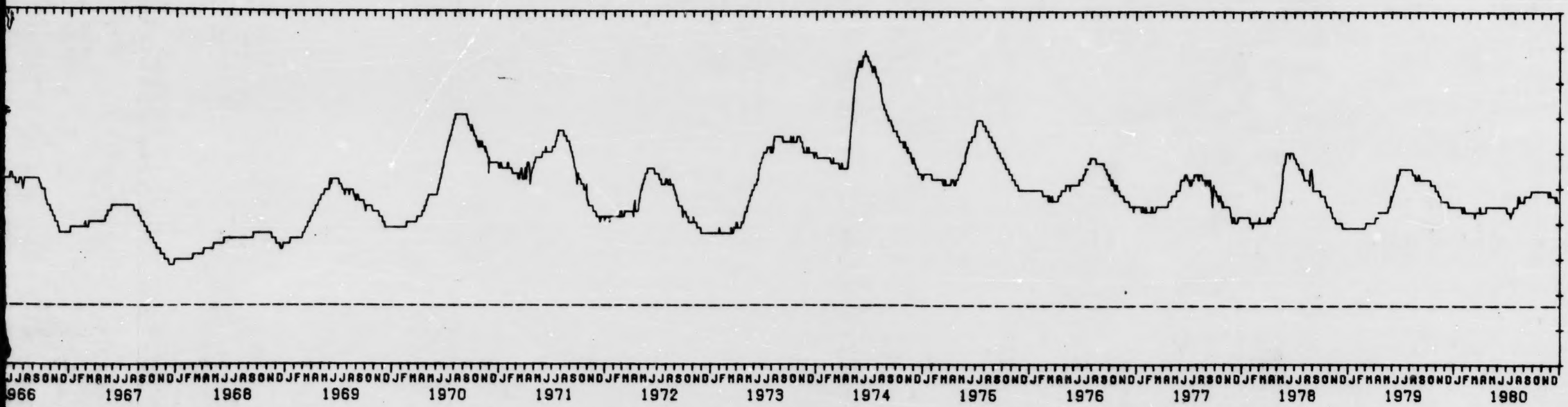
FIGURE 21

FLOW FREQUENCY
AND FLOW DURATION CURVES

BEAVER RIVER AT W.S.C.
COLD LAKE GAUGE 06AD006
(STUDY POINT 526)

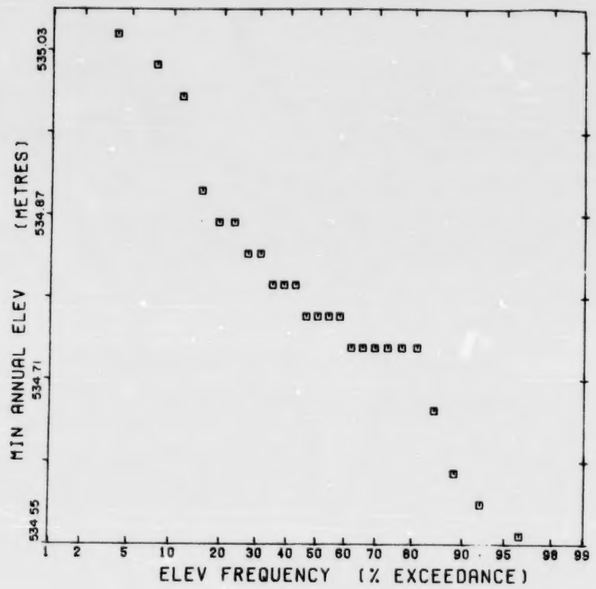


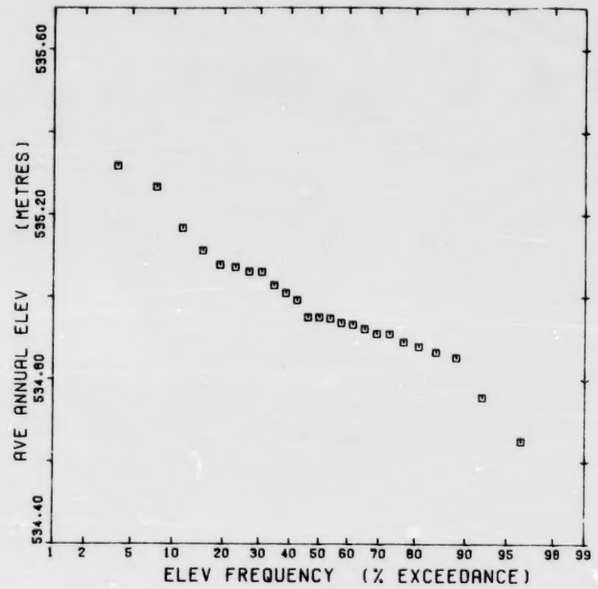
533 COLD LAKE WATER LEVELS

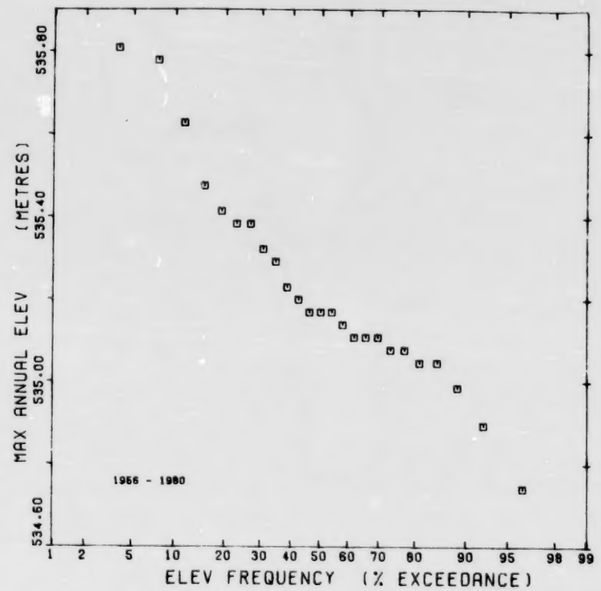


ER LEVELS

FIGURE 22
STAGE HYDROGRAPH
COLD LAKE
(STUDY POINT 533)







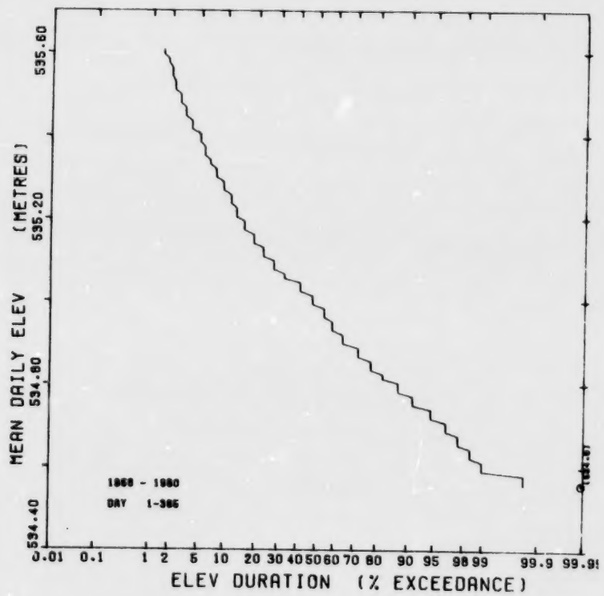
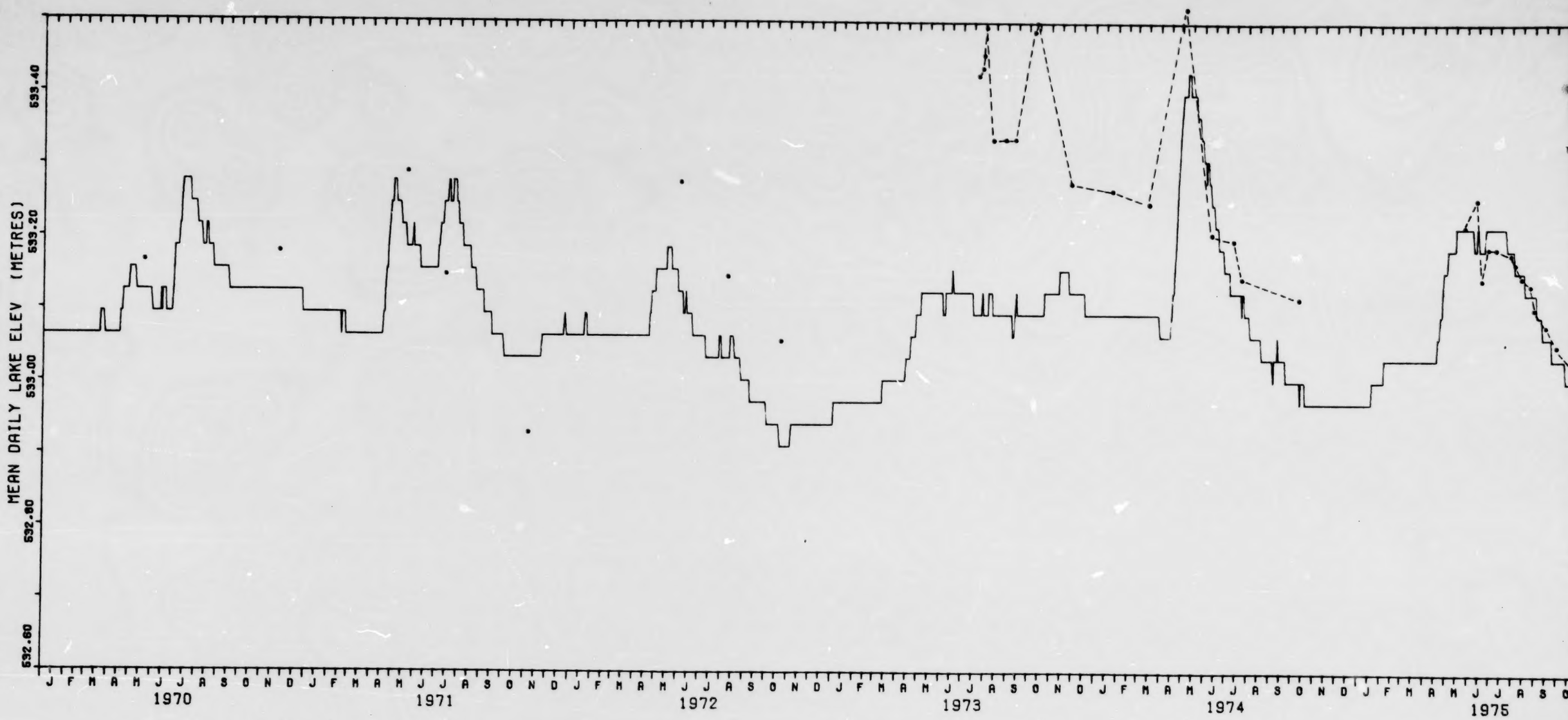


FIGURE 23

ELEVATION FREQUENCY AND DURATION CURVES

COLD LAKE
(STUDY POINT 533)



210 MOOSE LAKE

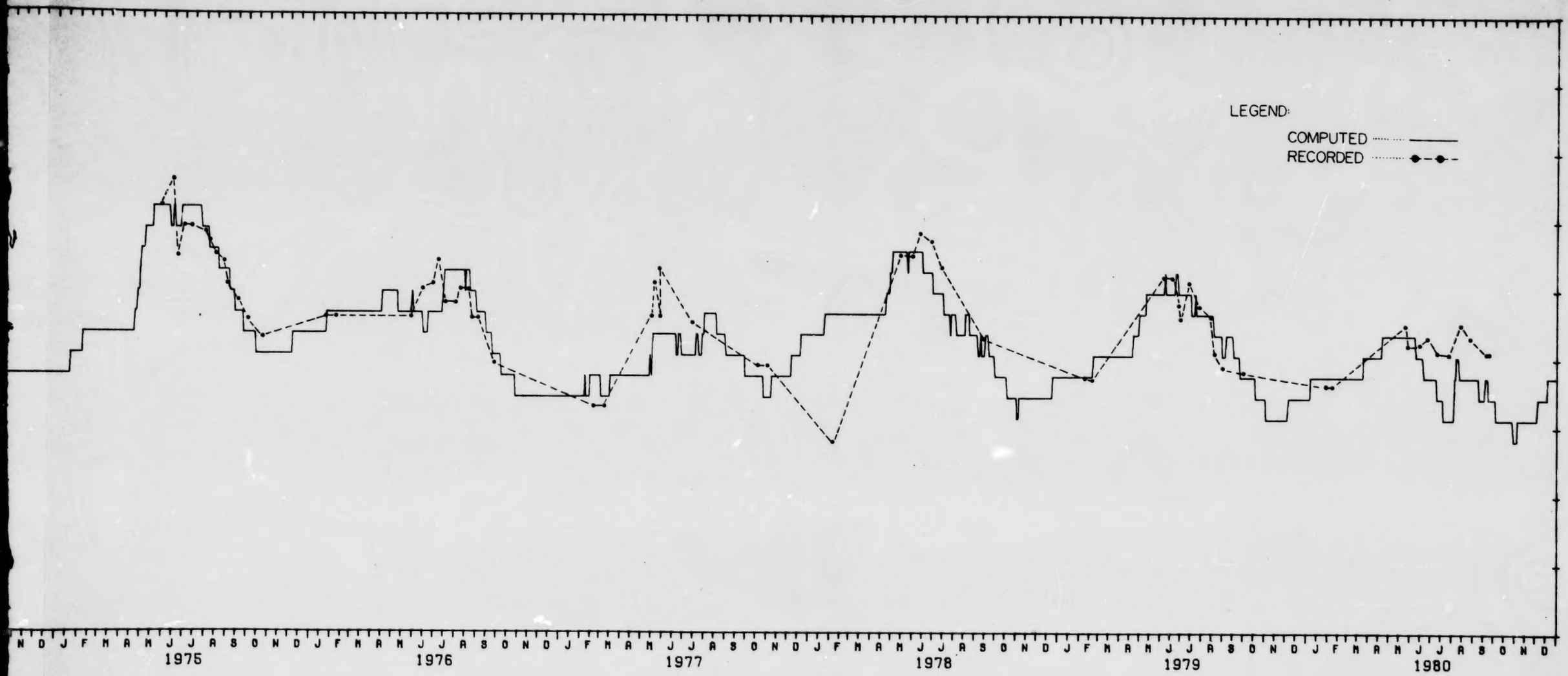
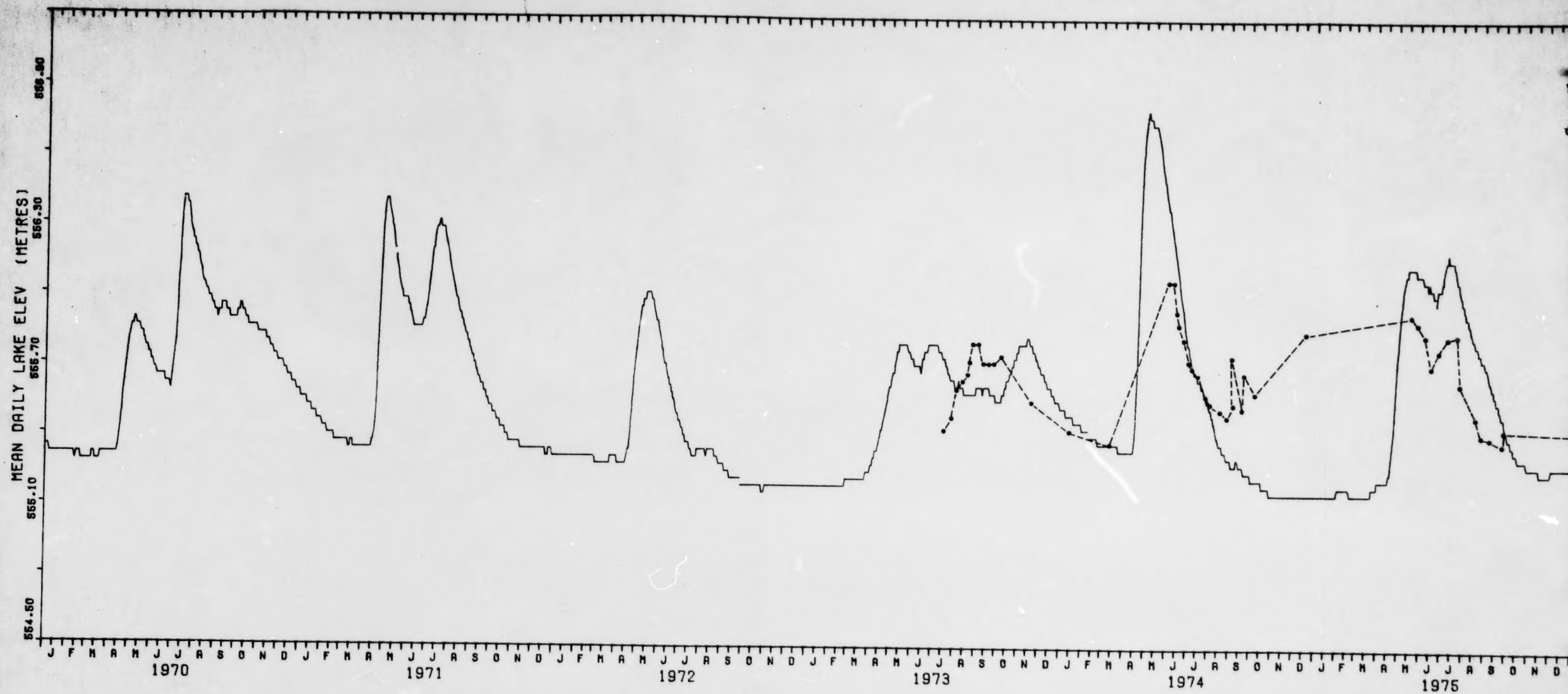


FIGURE 24

COMPARISON OF MODEL RESULTS
WITH RECORDED DATA

210 - MOOSE LAKE
WATER LEVELS



212 MANATOKAN LAKE

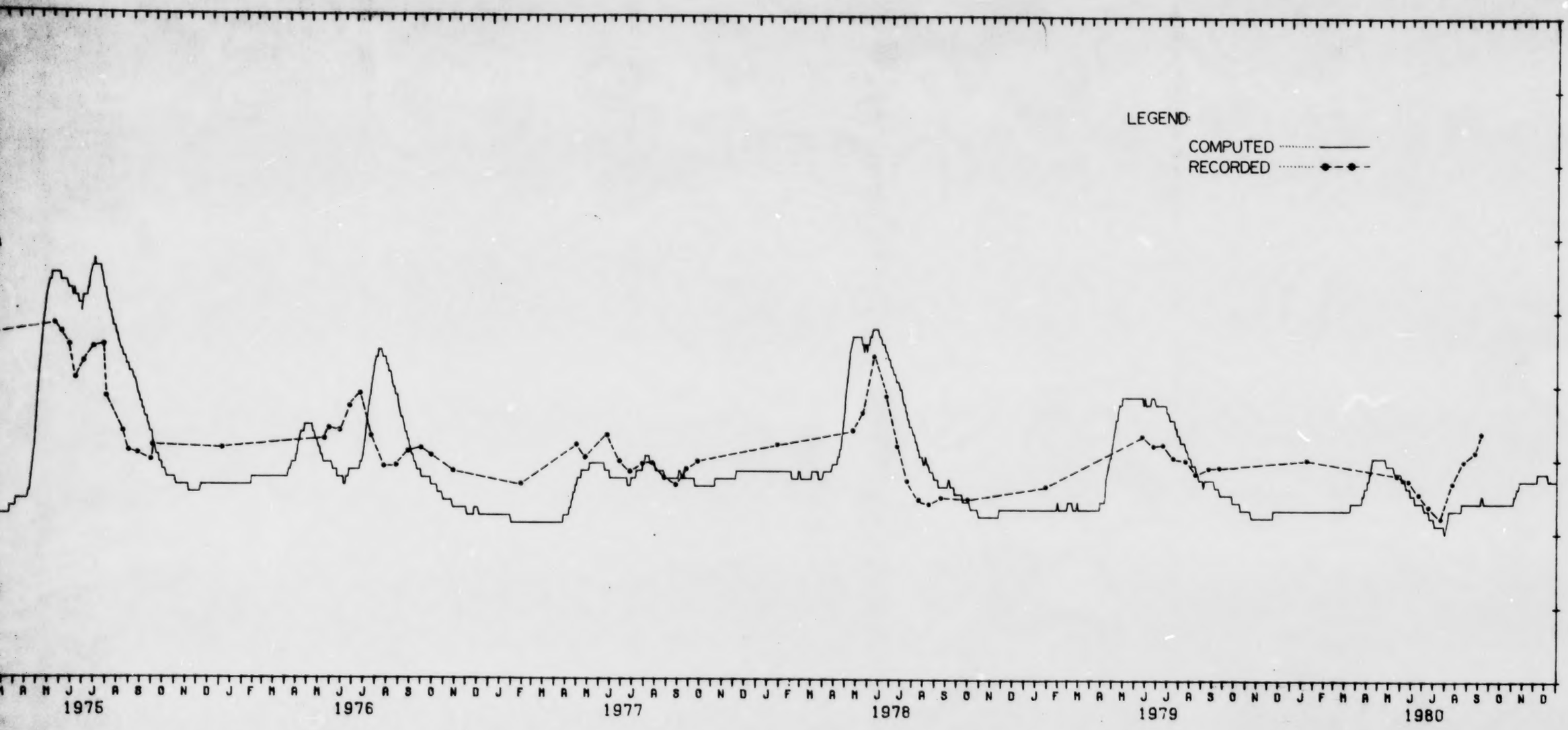
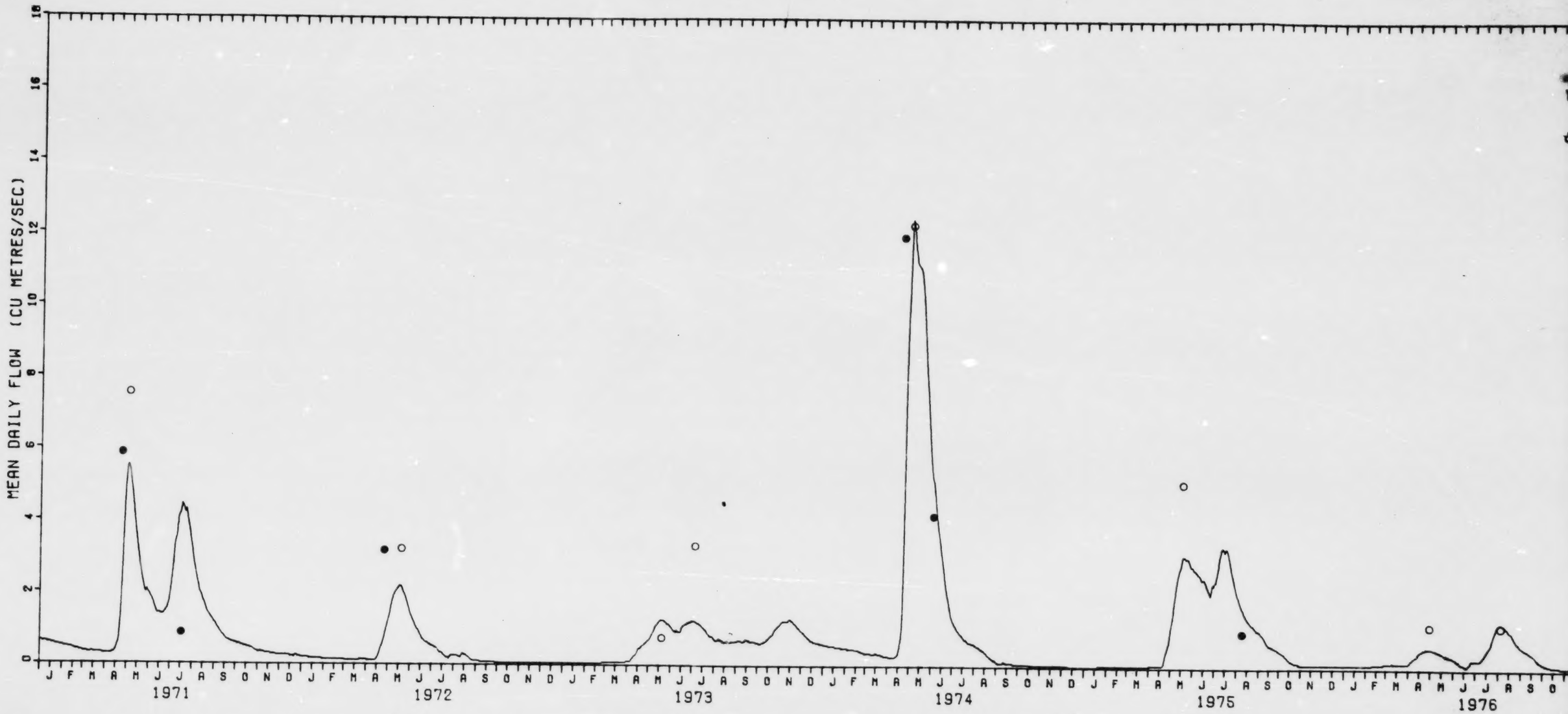


FIGURE 25

COMPARISON OF MODEL RESULTS WITH RECORDED DATA

212- MANATOKAN LAKE WATER LEVELS



212 MANATOKAN LAKE

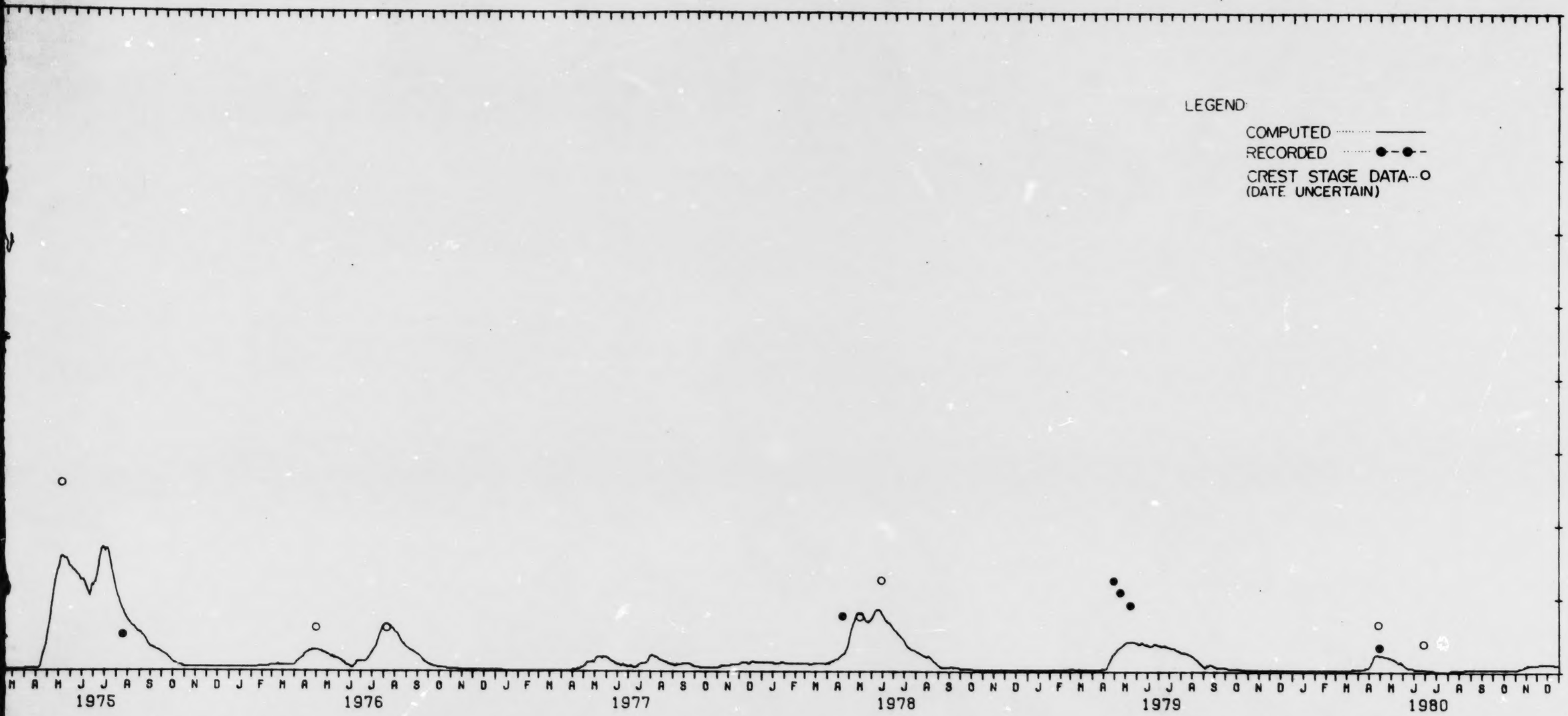
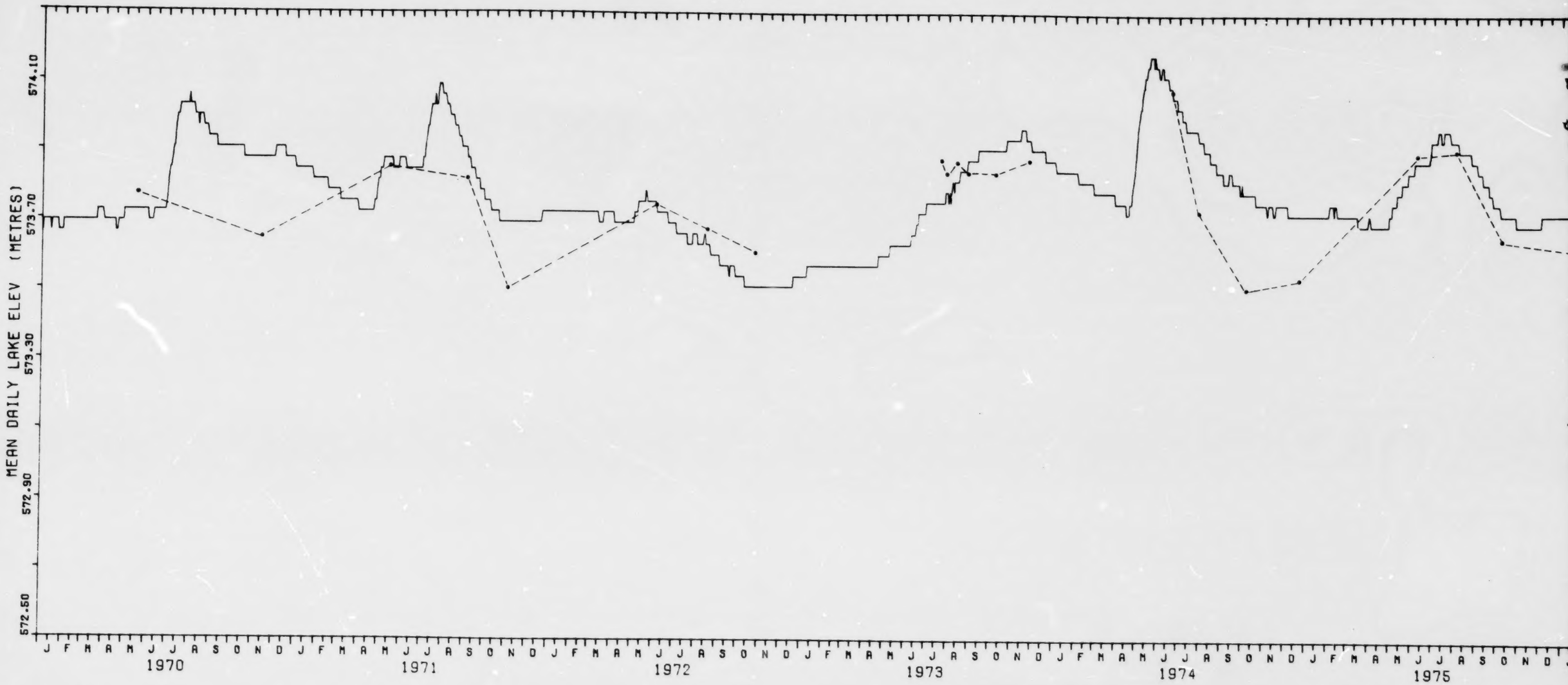


FIGURE 26

COMPARISON OF MODEL RESULTS
WITH RECORDED DATA

MANANATOKAN LAKE
OUTFLOW



220 MARIE LAKE

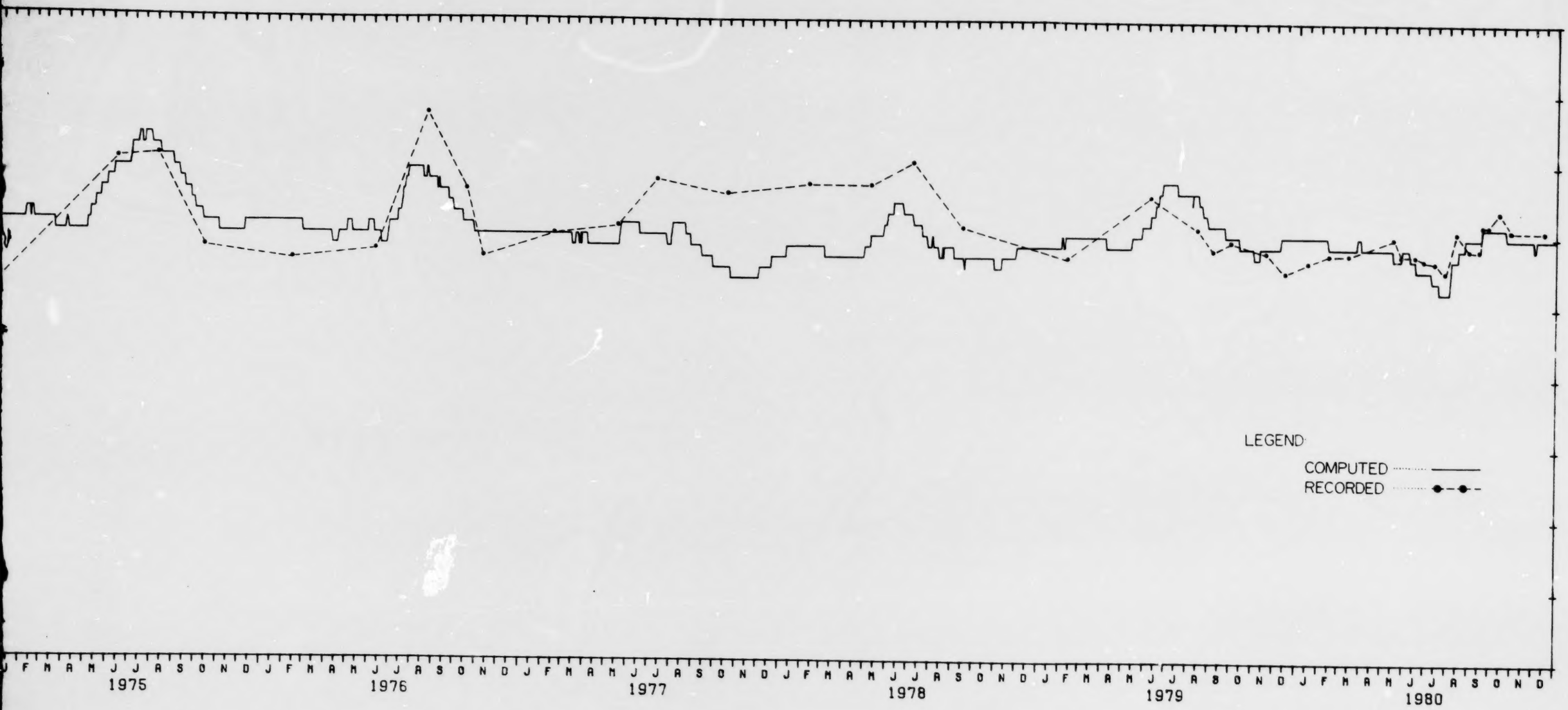


FIGURE 27

COMPARISON OF MODEL RESULTS
WITH RECORDED DATA

220 - MARIE LAKE
WATER LEVELS

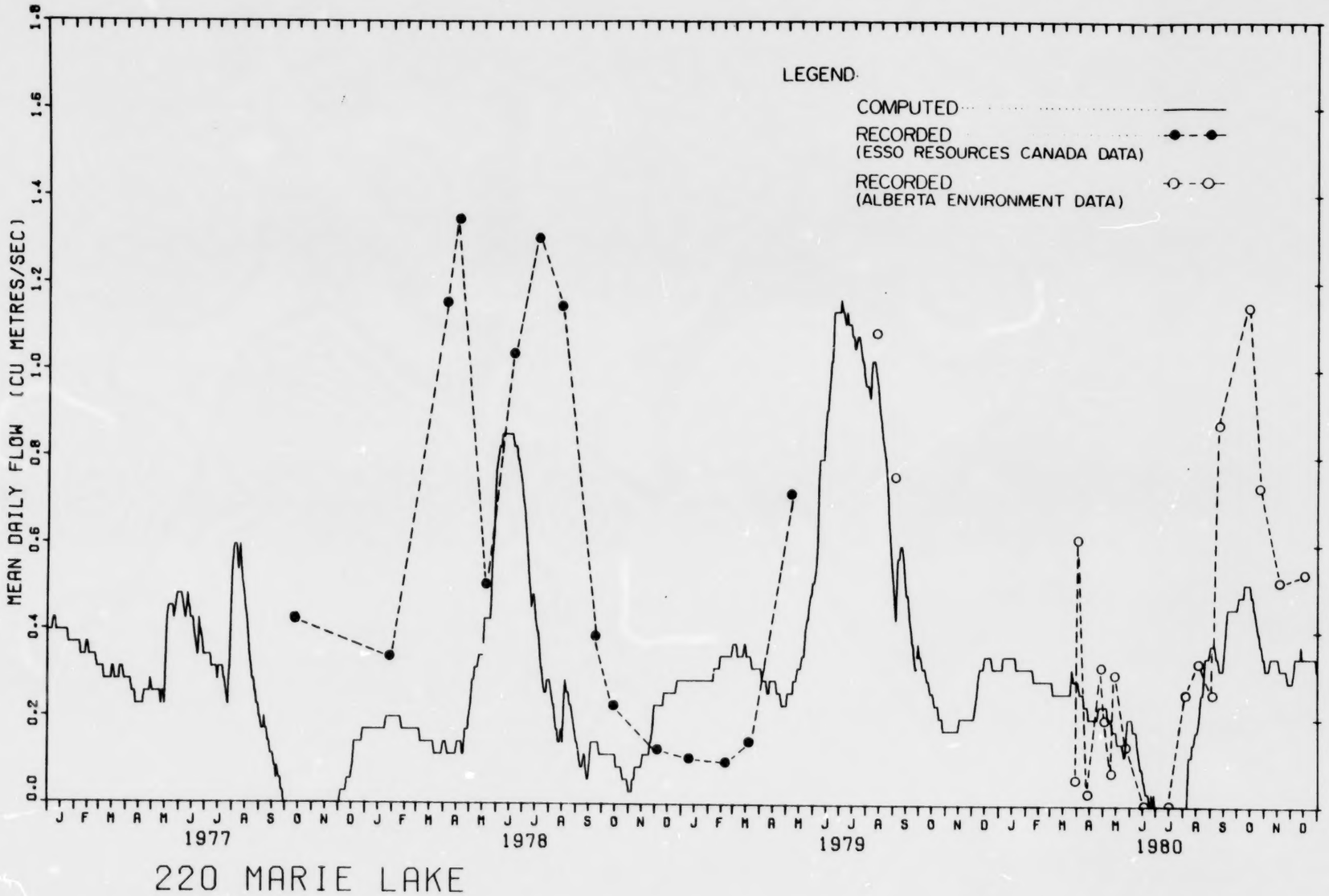
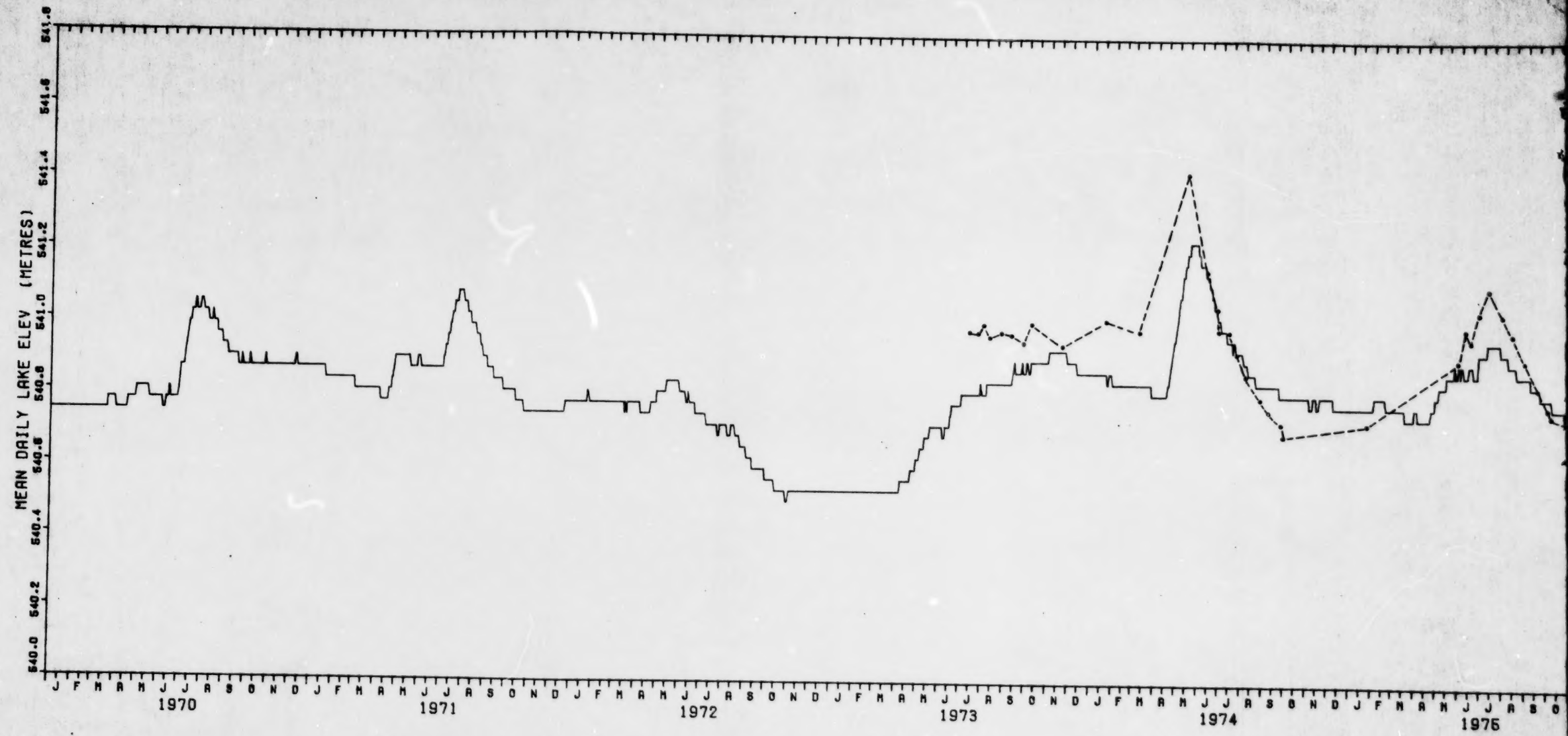


FIGURE 28
COMPARISON OF MODEL RESULTS
WITH RECORDED DATA

220 - MARIE LAKE
OUTFLOW



221 ETHEL LAKE

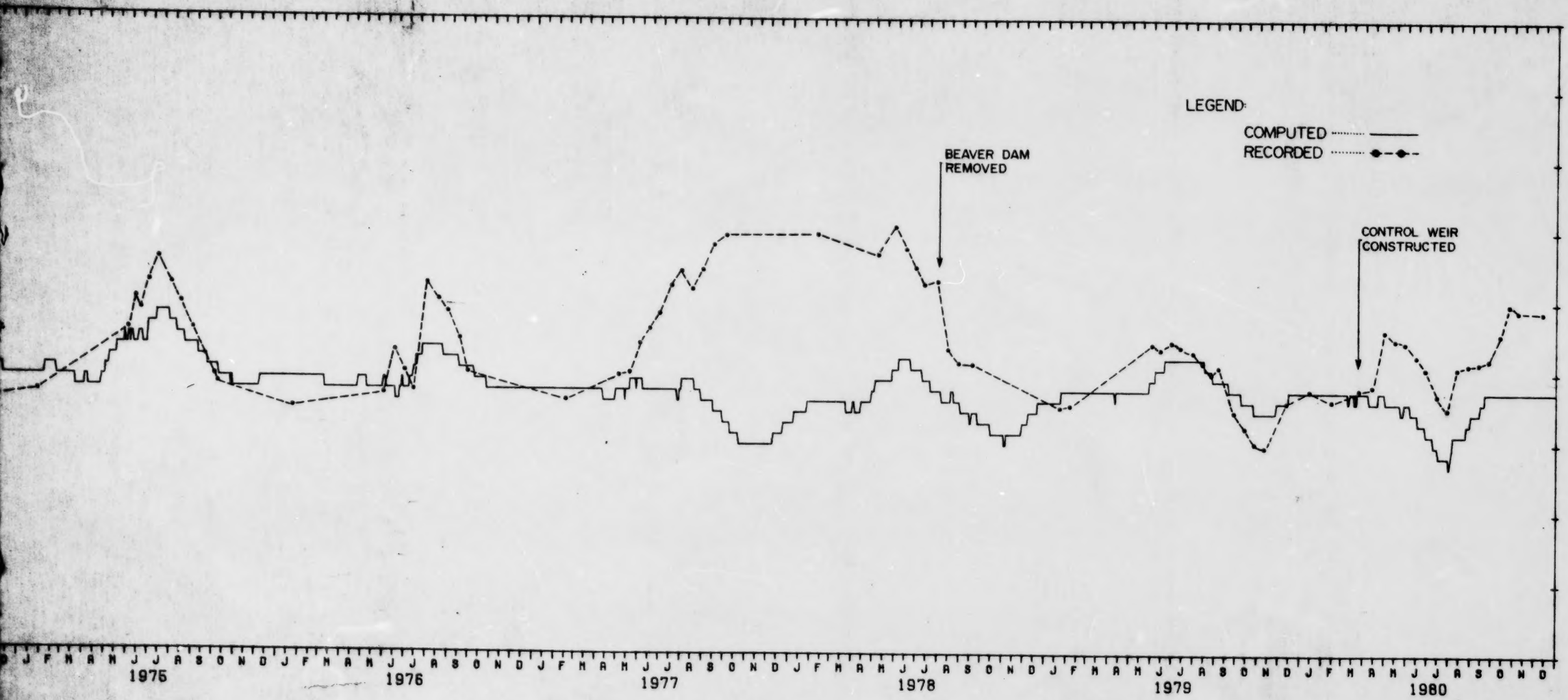


FIGURE 29

COMPARISON OF MODEL RESULTS WITH RECORDED DATA

221 - ETHEL LAKE WATER LEVELS

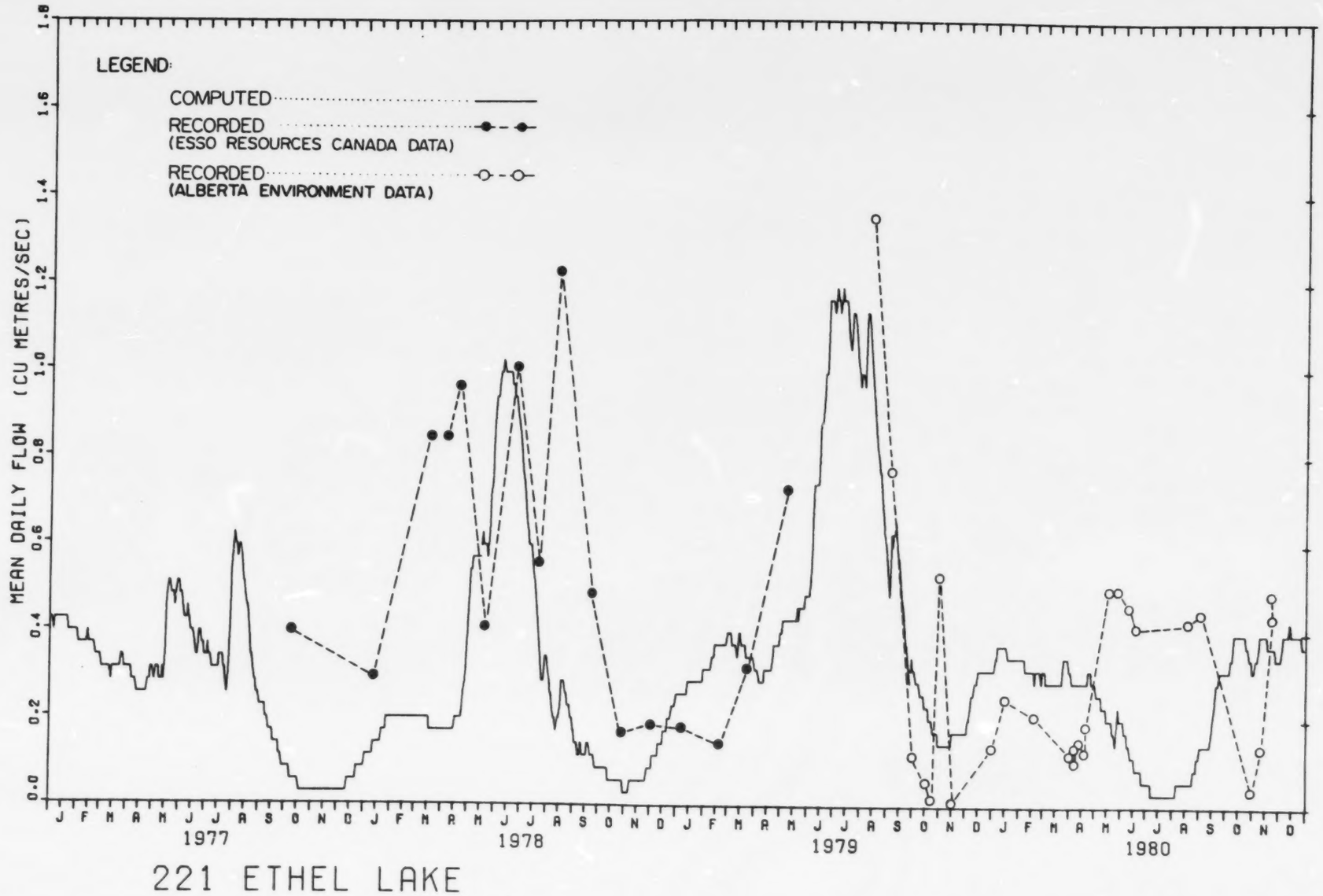
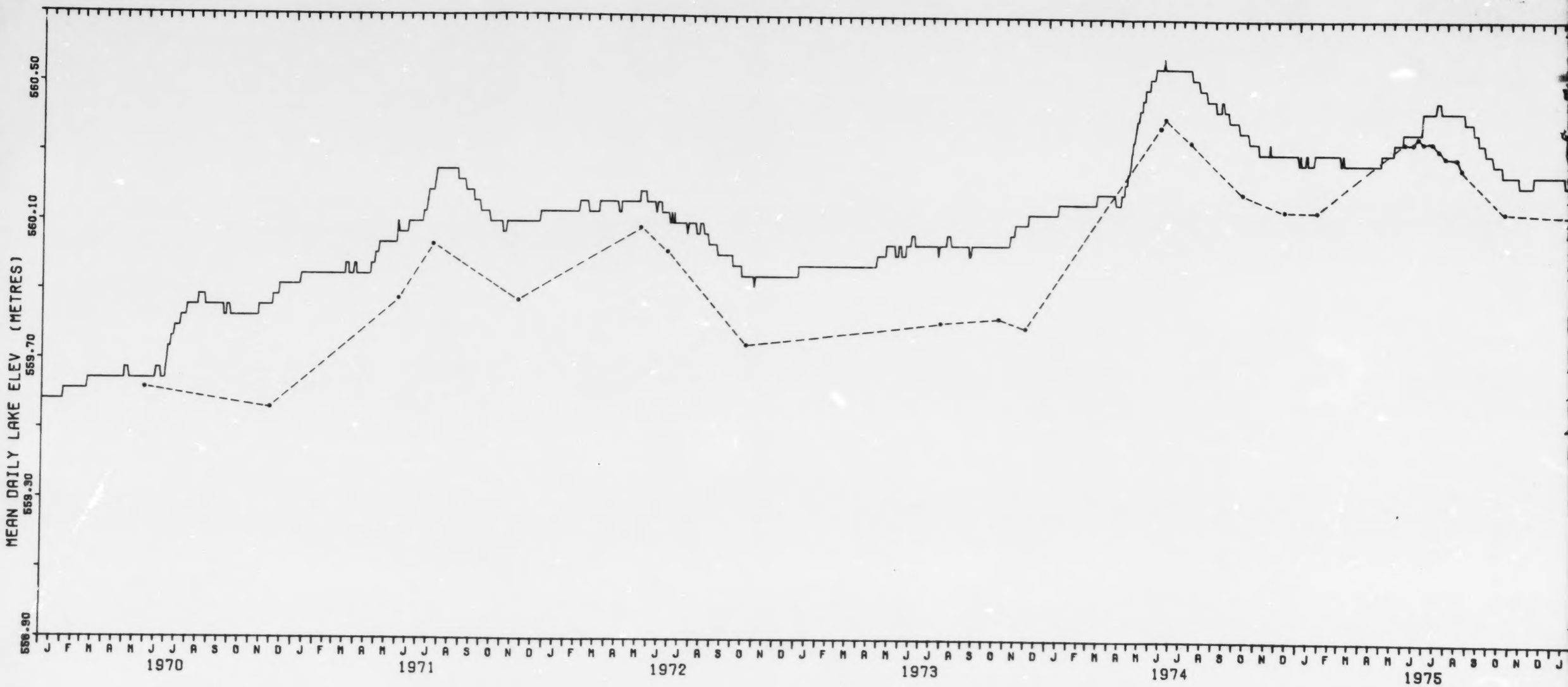


FIGURE 30
COMPARISON OF MODEL RESULTS
WITH RECORDED DATA

221 - ETHEL LAKE
OUTFLOW



223 MURIEL LAKE

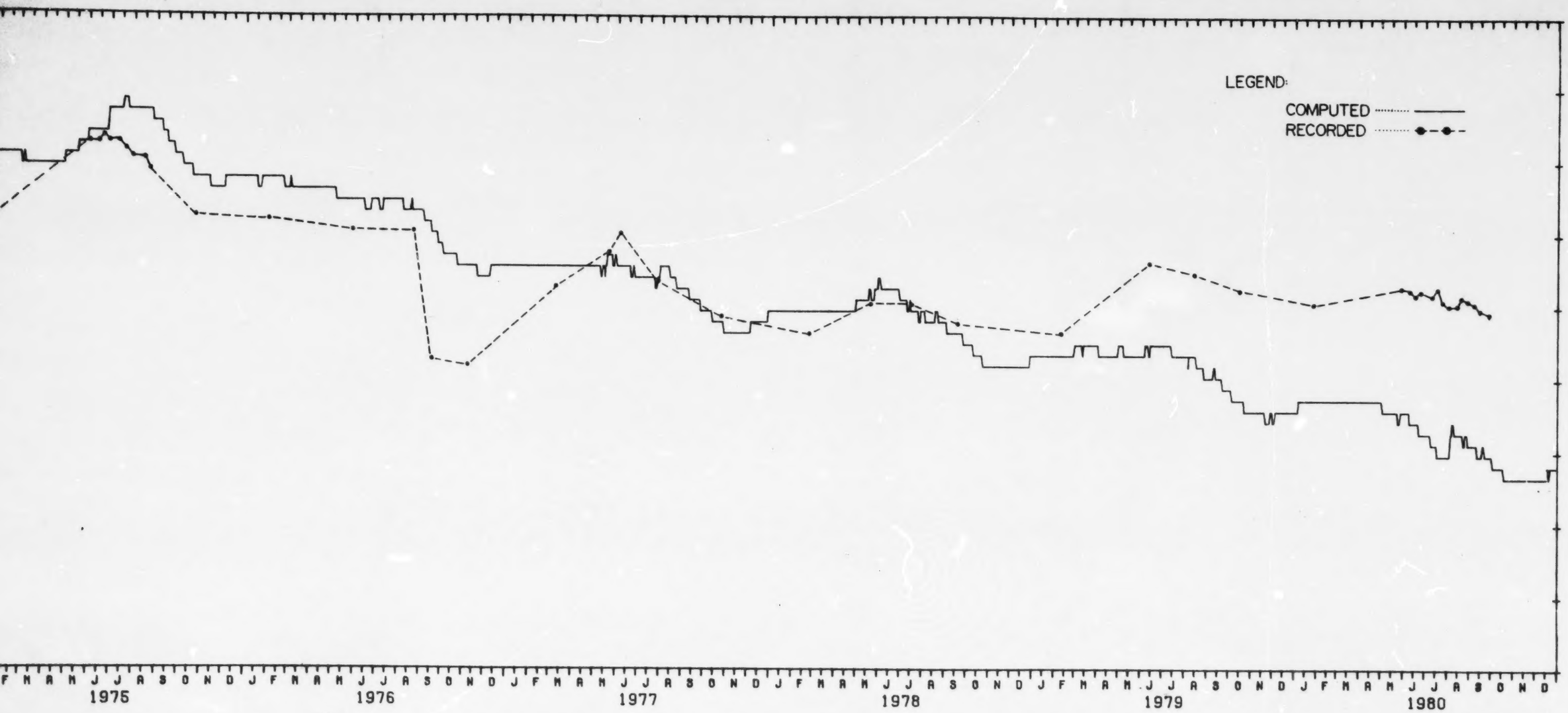
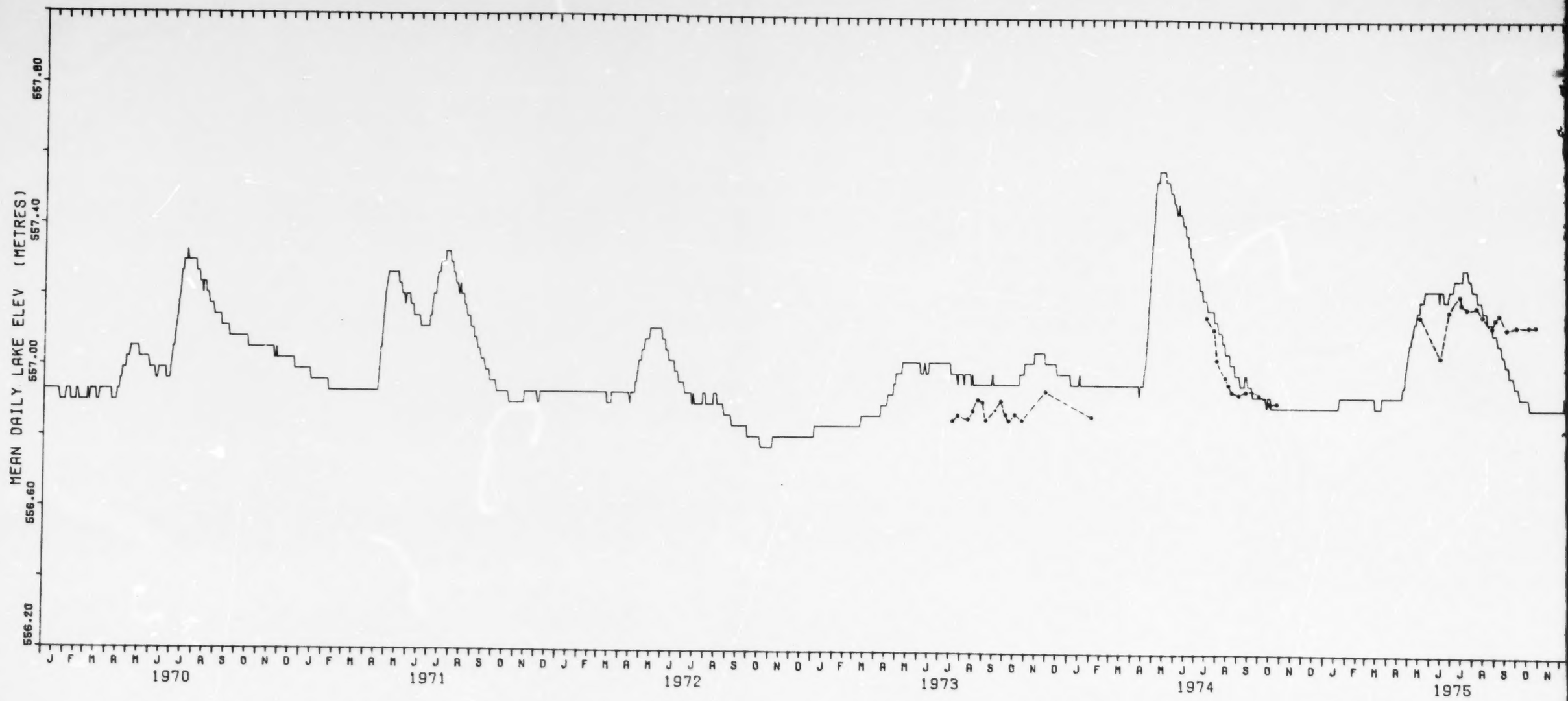


FIGURE 31

COMPARISON OF MODEL RESULTS WITH RECORDED DATA

223 - MURIEL LAKE WATER LEVELS



228 ANGLING LAKE

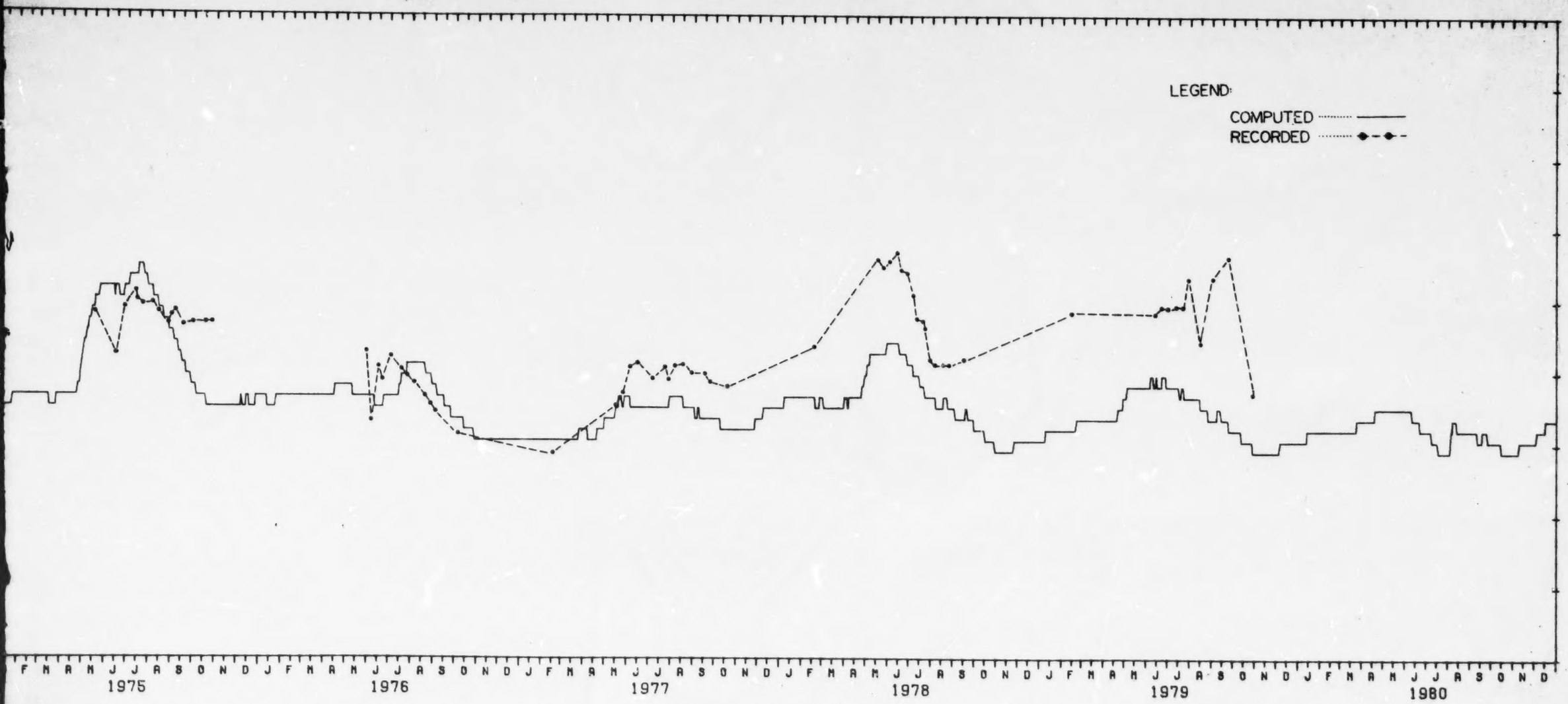


FIGURE 32

COMPARISON OF MODEL RESULTS
WITH RECORDED DATA

228 - ANGLING LAKE
WATER LEVELS

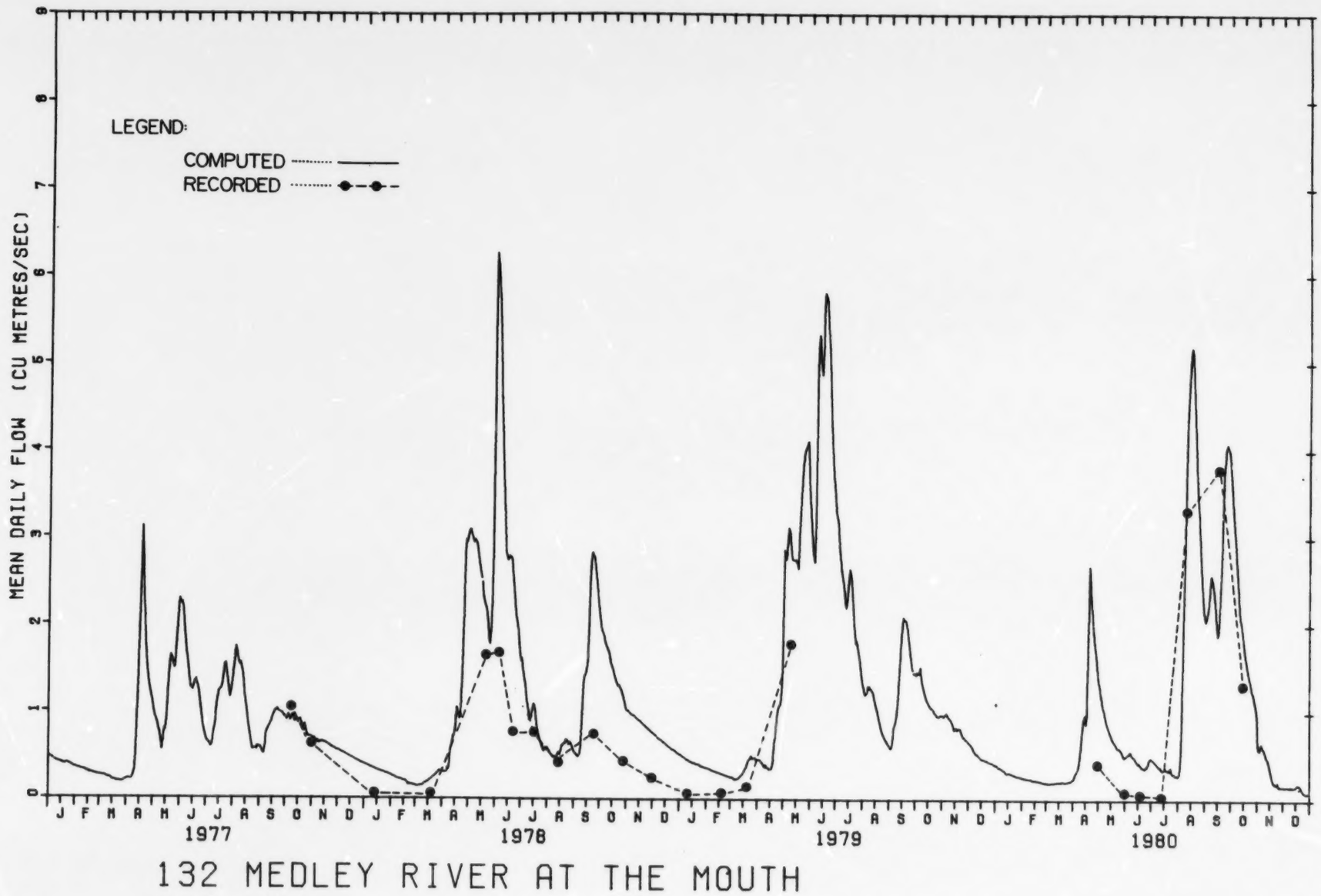


FIGURE 33

COMPARISON OF MODEL RESULTS WITH RECORDED DATA

132 – MEDLEY RIVER OUTFLOW

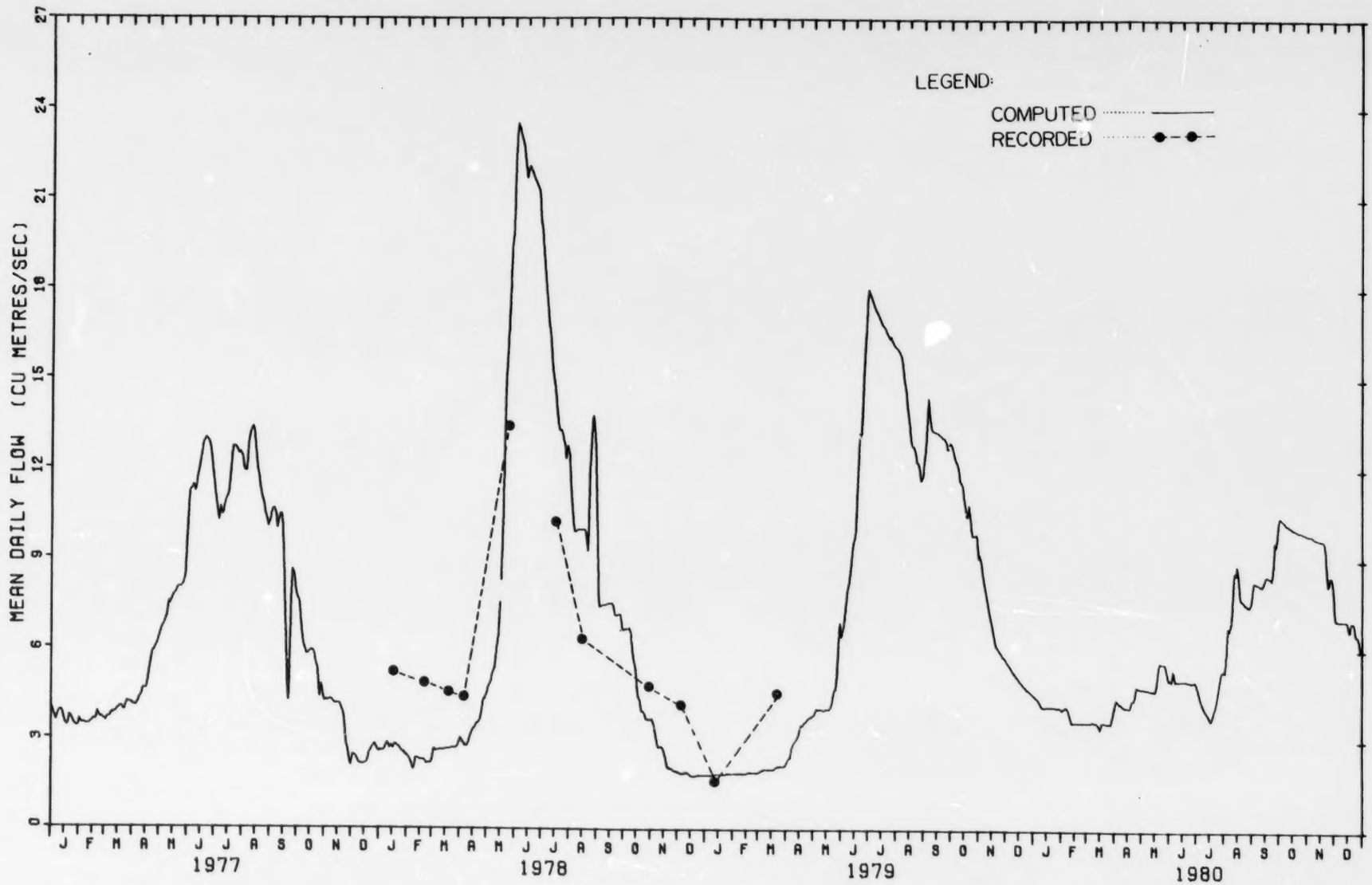


FIGURE 34
COMPARISON OF MODEL RESULTS
WITH RECORDED DATA

231 - PRIMROSE LAKE
OUTFLOW

APPENDIX A

SAMPLE MODEL DATA LISTING

This Appendix contains a complete listing of the SSARR model data deck used for the 1956 to 1959 simulation run. Model data are listed in the following pages and are described briefly below. For details of the data format the reader is referred to the SSARR User Manual (Reference 2 in the main report). Imperial units are used throughout.

The data consists of the following:

1. Job control cards. These consist of data to identify the model run, such as the date and run name.

2. Streamflow data stations - a list of stations and station labels for locations where streamflow and evaporation data are input (streamflow gauges and evaporation station 800).

3. Sum points and their locations. These are junctions, nodes, or locations other than lakes or river reaches at which output is required.

4. Local area runoff data. For each local area, two data lines occur; the first identifies the local area, and the second specifies the analog station and the yield factor applied to the analog flows to estimate the local area flows.

5. Lake evaporation/precipitation data. For each lake, evaporation/precipitation is specified as a percentage of station 800.

6. Dummy reservoir data. Four lines of data for each dummy reservoir specify reservoir storage characteristics such that a 1-foot change in reservoir level corresponds to 1 inch of runoff in the contributing watershed. These reservoirs are used to compute the accumulated simulation error (in inches over the basin) at locations where streamflows are recorded.

7. Lake elevation-discharge-storage tables. These tables specify lake outflow and storage volumes for the possible range in water levels. Storage volumes are defined to have a value of 0.0 acre feet at the elevation of the lake outlet sill.

8. River channel routing characteristics. These cards specify the number of reaches and values of the routing parameters n and KTS per reach.

9. Configuration data. These data form a "map" of the watershed; they specify the location of all stations with respect to other stations in the watershed.

10. Time control card - specifies the start and end dates of the simulation.

11. Initial conditions - specify lake elevations and stream discharges at the start of the run.

12. Dummy reservoir regulation cards. These cards specify initial and final conditions required in the operation of the dummy reservoirs.

13. Streamflow data for base stations. These data are provided for the four-year period 1956 - 1959 (4 years is the maximum length of simulation possible in one SSARR model run).

14. Plot control cards - control graphical output.

```
 1            *** AE-COLD SSARR MODEL VI ***      REVISED APRIL 1982 ***
 2            *** BEAVER RIVER - COLD LAKE  ***    1955 - 1959
 3      JOB        8101270482   0        1 P1        AE-COLD - BEAVER RIVER MODEL SIMULATION
 4            *** STREAMFLOW DATA STATIONS ***
 5      CC01       502          0                    BEAVER AT GOODRIDGE OSAA001
 6      CC01       508                               WSC FLOWS WOLF R. OSAB002
 7      CC01       506          0                    SAND RIVER OSAB001
 8      CC01       516          0                    JACKFISH CR. OSAC001
 9      CC01       526          0                    BEAVER R. AT COLD LAKE OSAD005
10      CC01       533          0                    COLD L OUTFLOWS GEN FROM RECORDED LAKE LEVELS
11      CC01       131          0                    PRIMROSE L LOCAL + EVAP (CALCULATED)
12      CC01       133          0                    COLD L LOCAL + EVAP (CALCULATED)
13      CC01       507          0                    CALCULATED SAND RIVER LOCAL U/S OF WOLF
14      CC01       930          0                    CALCULATED LOCAL BEAVER D/S GOODRIDGE
15      CC01       800          0                    NET EVAP. BASED ON COLD LAKE
16            *** ADDITIONAL SUM POINTS ***
17      CC01       503          2                    SUM BEAVER RIVER U/S OF SAND
18      CC01       505          2                    SUM SAND R. U/S WOLF
19      CC01       507          2                    SUM SAND R. D/S WOLF
20      CC01       508          0                    SUM SAND RIVER U/S OF BEAVER
21      CC01       510          0                    MOOSE RIVER AT MOUTH
22      CC01       511          0                    BEAVER RIVER D/S SAND RIVER
23      CC01       512          2                    BEAVER RIVER D/S MANATOKAN
24      CC01       515          2                    BEAVER RIVER U/S JACKFISH
25      CC01       517          0                    BEAVER RIVER D/S JACKFISH
26      CC01      5171          2                    BEAVER RIVER U/S MARIE CR.
27      CC01       521          2                    MARIE CR. AT MOUTH
28      CC01       522          0                    BEAVER RIVER D/S MARIE
29      CC01       525          2                    MURIEL CR. AT MOUTH
30      CC01       529          2                    SUM REITA CR. AT MOUTH
31      CC01       530          2                    SUM BEAVER RIVER D/S REITA
32      CC01       534          2                    SUM BEAVER RIVER AT BORDER
33            *** LOCAL AREA RUNOFF ***
34      CC01       104          0                    CARIBOU INFLOW
35      CC02       104                                907        405
36      CC01       105          0                    SAND R LOCAL U/S WOLF
37      CC02       105                                907        505
38      CC01       107          0                    FISHER CR.
39      CC02       107                                907         80
40      CC01       108          0                    SAND R. LOCAL D/S WOLF
41      CC02       108                                505       1060
42      CC01       116          0                    TUCKER L LOCAL
43      CC02       116                                516        870
44      CC01       117          0                    JACKFISH CK LOCAL
45      CC02       117                                516        380
46      CC01       103          0                    BEAVER R LOCAL U/S OF SAND & MOOSE CONF
47      CC02       103                                516       1110
48      CC01       109          0                    SAND R LOCAL D/S OF GAUGE 51
49      CC02       109                                516        240
50      CC01       110          0                    MOOSE L LOCAL
51      CC02       110                                516       1590
52      CC01       111          0                    MOOSE R LOCAL
53      CC02       111                                930         33
54      CC01       112          0                    MANATOKAN L LOCAL
55      CC02       112                                516        890
56      CC01       115          0                    BEAVER R LOCAL U/S OF JACKFISH
57      CC02       115                                930        120
58      CC01       122          0                    BEAVER R LOCAL U/S MARIE CK
59      CC02       122                                930         80
60      CC01       118          0                    BURNT L LOCAL

61      CC02       118                                907         28
62      CC01       119          0                    MAY L LOCAL
63      CC02       119                                907         12
64      CC01       120          0                    MARIE L LOCAL
65      CC02       120                                907         34
66      CC01       121          0                    ETHEL L LOCAL
67      CC02       121                                516        170
68      CC01      1211          0                    MARIE CK U/S MOUTH LOCAL
69      CC02      1211                                930         57
70      CC01       123          0                    MURIEL L LOCAL
71      CC02       123                                516        880
72      CC01       124          0                    CHARLOTTE L LOCAL
73      CC02       124                                516        410
74      CC01       125          0                    MURIEL CK MOUTH LOCAL
75      CC02       125                                930         74
76      CC01       130          0                    BEAVER R @ COLD L LOCAL
77      CC02       130                                930         20
78      CC01       127          0                    REITA L. LOCAL
79      CC02       127                                516        120
80      CC01       128          0                    ANGLING L. LOCAL
81      CC02       128                                516        330
82      CC01       129          0                    REITA CK. LOCAL
83      CC02       129                                930         15
84      CC01       132          0                    MEDLEY R LOCAL
85      CC02       132                                907        130
86      CC01       134          0                    BEAVER R. REITA CK. TO BORDER
87      CC02       134                                930        250
88            *** LAKE EVAPORATION ***
89      CC01       804          0                    CARIBOU EVAPO
90      CC02       804                                800         08
91      CC01       816          0                    TUCKER LAKE EVA.  1.3% (800)
92      CC02       816                                800         13
93      CC01       810          0                    MOOSE LAKE EVA.  7.8% (800)
94      CC02       810                                800         78
95      CC01       812          0                    MANATOKAN LAKE EVA.  0.9% (800)
96      CC02       812                                800         09
97      CC01       818          0                    BURNT LAKE EVA.  0.9% (800)
98      CC02       818                                800         09
99      CC01       819          0                    MAY LAKE EVA.  0.8% (800)
100     CC02       819                                800         08
101     CC01       820          0                    MARIE LAKE EVA.  7.0% (800)
102     CC02       820                                800         70
103     CC01       821          0                    ETHEL LAKE EVA.  0.9% (800)
104     CC02       821                                800         09
105     CC01       823          0                    MURIEL LAKE EVA.  13.2% (800)
106     CC02       823                                800        132
107     CC01       824          0                    CHARLOTTE LAKE EVA.  2.1% (800)
108     CC02       824                                800         21
109     CC01       827          0                    REITA LAKE EVA.  2.4% (800)
110     CC02       827                                800         24
111     CC01       828          0                    ANGLING LAKE EVA.  1.1% (800)
112     CC02       828                                800         11
113            *** DUMMY RESERVOIR ***
114     CC01      7080          0                    CALC SAND FLOWS
115     CC01      7081          0                    SIGN CHANGES
116     CC02      7081 1
117     CL01      7082          0 0                  DUM RES-SUM C&R
118     CL02      7082                                     800     -800
119     C101      7082     -1000                 -1013333   1000                    1013333
120     CC01      7180          0                    CALC. FLOWS AT JACKFISH CR.
```

JOB CONTROL

STREAMFLOW DATA STATIONS

SUM POINTS

SUM OF LOCAL DATA

EVAPORATION

DUMMY RESERVOIR DATA

```
240     C111     228    182709     .04          510 182727    .625          800
241     C112     228    182798      35         1820 182857     50         2720
242     C113     228    182887      75         3150 182903    100         3400
243     C114     228    182929     150         3770 182946    200         4000
244     C115     228    183021     500         5150 183113   1000         8500
245     C116     228    183241    2000         8400 183343   3000         9900
246     C117     228    183503    8000       123009999999999999999     999999999
247     CL01     231        2 0        PRIMROSE LAKE
248     CL02     231                          33058  31842
249     C110     231     31842    .001       -720000  32288    .001           10 PRIM
250     C111     231     32349       5        50000  32375     25        80000
251     C112     231     32434      75       145000  32484    150       175000
252     C113     231     32497     300       213000  32529    500       250000
253     C114     231     32585    1000       310000  32684   2000       420000
254     C115     231     32835    4000       580000  33058   8000       835000
255     C116     231    999999999999999    913999999
256     CL01     233        2 0          COLD LAKE
257     CL02     233                          178245 174885
258     C110     233    174885    .001       -212000 174987    .001      -122885 COLD
259     C111     233    175295      20       174300 175393     30       263500
260     C112     233    175442     140       306100 175492    335       352700
261     C113     233    175541     875       397200 175590   1100       436000
262     C114     233    175656    1825       498000 175721   2045       554500
263     C115     233    175787    2470       613000 175882   2825       670000
264     C116     233    176245    3530      1000000999999999999999     999999999
265          *** RIVER CHANNEL ROUTING CHARACTERISTICS ***
266     CR01     304        0 0          SAND R D/S CARIBOU
267     CR02     304                 80500  70
268     CR01     307        0 0          SAND R D/S WOLF
269     CR02     307                 30500 100
270     CR01     315        0 0          JACKFISH CR.
271     CR02     315                 3050   41
272     CR01     302        0 0          BEAVER RIVER  GOODRIDGE TO U/S MOOSE
273     CR02     302                 3050  120
274     CR01     305        0 0          SAND RIVER  SAND R. GAUGE TO MOUTH
275     CR02     305                 3050  100
276     CR01     310        0 0          MOOSE RIVER  MOOSE LAKE TO MOUTH
277     CR02     310                 3050  100
278     CR01     314        0 0          BEAVER RIVER  D/S MANATOKAN TO U/S JACKFISH
279     CR02     314                 3050  150
280     CR01     317        0 0          BEAVER RIVER D/S JACKFISH TO U/S MARIE
281     CR02     317                 3050  240
282     CR01     321        0 0          MARIE CR.
283     CR02     321                 3050   45
284     CR01     324        0 0          MURIEL CR.
285     CR02     324                 4050   50
286     CR01     325        0 0          REITA CR.
287     CR02     325                 3050   45
288     CR01     330        0 0          BEAVER RIVER D/S REITA CR. TO BORDER
289     CR02     330                 3050  225
290     CR01     331        0 0          MARTINEAU RIVER
291     CR02     331                 5050   55
292          *** CONFIGURATION ***
293     P1       507
294     P2       530
295     P4       500
296     P5       104       204
297     P6       504       204
298     P7       204       304
299     P8       304       505
```

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300     P9       105       505
301     P10      505       507
302     P11      107       507
303     P12      506       507
304     P13      507       307
305     P14      307      7050
306     P15      108      7050
307     P16     7050      7051
308     P17     7051      7052
309     P18      508      7052       308
310     P19     7052
311     P27      515      7152       517
312     P20      115       215
313     P21      515       215
314     P22      215       315
315     P23      315      7150
316     P24      117      7150
317     P25     7150      7151
318     P26     7151      7152
319     P28     7152
320     P29      502       302
321     P30      302       503
322     P31      103       503
323     P32      503       511
324     P33      305       505
325     P34      109       509
326     P35      509       511
327     P38      110       210
328     P37      510       210
329     P38      210       310
330     P39      310       510
331     P40      111       510
332     P41      510       511
333     P42      511       512
334     P43      112       212
335     P44      512       212
336     P45      212       512
337     P46      512       314
338     P47      314       515
339     P48      115       515
340     P49      515       517
341     P50      517       317
342     P51      317      5171
343     P52      122      5171
344     P53     5171       522
345     P54      118       218
346     P55      518       218
347     P56      218       219
348     P57      119       219
349     P58      519       219
350     P59      219       220
351     P60      120       220
352     P61      520       220
353     P62      220       221
354     P63      121       221
355     P64      521       221
356     P65      321       321
357     P66      321       521
358     P67     1211       521
359     P68      521       522
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LAKE ELEVATION-DISCHARGE-STORAGE TABLES

RIVER CHANNEL ROUTING CHARACTERISTICS

CONFIGURATION DATA

480	SD	SO28120 9 8581	706	685	630	585	546	513	483	459
481	SD	SO2812017 8581	[illegible]	417	405	384	372	361	338	327
482	SD	SO27120258581	321	309	300	294	288	278	285	0
483	SD	SO28120 1 9581	281	303	312	324	336	346	351	350
484	SD	SO28120 9 9581	357	348	342	330	315	312	297	291
485	SD	SO2812017 9581	279	270	275	324	411	531	630	724
486	SD	SO2812025 9581	757	802	832	835	820	778	0	0
487	SD	SO28120 110581	724	685	648	605	573	531	501	468
488	SD	SO28120 910581	453	429	408	384	378	354	342	330
489	SD	SO2812017105 81	315	306	297	288	278	272	264	258
490	SD	SO27120251058 1	248	238	223	216	213	238	265	0
491	SD	SO28120 111581	271	291	300	312	336	327	243	251
492	SD	SO28120 911581	257	286	285	228	207	205	197	190
493	SD	SO2812017115 81	182	183	185	178	176	171	170	162
494	SD	SO2812025115 81	158	155	152	148	142	143	0	0
495	SD	SO28120 112581	140	133	126	112	103	93	86	73
496	SD	SO28120 912581	68	62	62	60	60	59	57	60
497	SD	SO2812017125 81	60	59	59	59	59	59	58	57
498	SD	SO27120251258 1	58	58	58	58	58	58	56	0
499	SD	SO28120 1 1571	54	52	47	45	44	43	43	42
500	SD	SO28120 9 1571	38	36	34	30	27	24	23	21
501	SD	SO2812017 1571	19	19	19	18	18	18	14	13
502	SD	SO27120251571	12	11	9	9	9	9	8	0
503	SD	SO28120 1 2571	8	8	18	20	17	15	14	14
504	SD	SO28120 9 2571	13	12	11	10	9	10	10	8
505	SD	SO2812017 2571	8	8	8	8	8	8	2	2
506	SD	SO2812025 2571	2	2	1	1	0	0	0	0
507	SD	SO28120 1 3571	1	1	1	2	4	8	9	13
508	SD	SO28120 9 3571	14	15	15	14	13	13	13	12
509	SD	SO2812017 3571	12	12	12	13	13	13	14	15
510	SD	SO27120253571	16	16	16	19	24	28	32	0
511	SD	SO28120 1 4571	37	64	78	91	121	162	174	184
512	SD	SO28120 9 4571	186	177	176	173	161	164	183	194
513	SD	SO2812017 4571	212	228	245	432	474	600	587	652
514	SD	SO2812025 4571	853	754	814	688	670	621	0	0
515	SD	SO28120 1 5571	588	558	526	507	486	474	459	447
516	SD	SO28120 9 5571	428	417	408	390	372	378	372	369
517	SD	SO2812017 5571	383	357	342	338	312	306	297	288
518	SD	SO27120255571	277	269	264	257	244	235	231	0
519	SD	SO28120 1 6571	222	216	212	208	200	194	190	191
520	SD	SO28120 9 6571	187	183	182	179	176	173	167	159
521	SD	SO2812017 6571	152	148	142	138	138	134	130	127
522	SD	SO2812025 6571	125	122	121	120	120	118	0	0
523	SD	SO28120 1 7571	121	128	125	128	127	143	145	145
524	SD	SO28120 9 7571	145	143	140	138	134	132	134	139
525	SD	SO2812017 7571	138	135	135	134	135	137	145	145
526	SD	SO27120257571	148	152	155	150	145	142	139	0
527	SD	SO28120 1 8571	138	131	125	124	121	117	111	111
528	SD	SO28120 9 8571	109	107	108	112	120	118	117	115
529	SD	SO2812017 8571	114	112	109	105	103	101	98	100
530	SD	SO27120258571	105	100	101	101	100	89	95	0
531	SD	SO28120 1 9571	95	94	98	101	101	101	101	103
532	SD	SO28120 9 9571	103	105	106	108	109	112	109	108
533	SD	SO2812017 9571	105	103	99	98	96	95	91	79
534	SD	SO2812025 9571	85	84	82	80	79	78	0	0
535	SD	SO28120 110571	77	87	103	103	101	109	115	121
536	SD	SO28120 910571	122	122	127	133	142	151	160	171
537	SD	SO2812017105 71	185	187	188	212	236	282	251	242
538	SD	SO27120251057 1	249	259	303	297	291	341	303	0
539	SD	SO28120 111571	183	180	183	184	148	123	108	114
540	SD	SO28120 911571	123	127	138	138	138	134	124	114
541	SD	SO2812017115 71	93	84	75	65	64	65	63	60
542	SD	SO2812025115 71	61	61	57	52	56	59	0	0
543	SD	SO28120 112571	62	62	62	61	62	62	62	61
544	SD	SO28120 912571	62	62	62	54	52	51	48	48
545	SD	SO2812017125 71	47	45	45	44	44	45	45	45
546	SD	SO27120251257 1	44	43	42	41	41	39	38	0
547	SD	SO28120 1 1581	38	39	41	41	41	41	41	35
548	SD	SO28120 9 1581	40	40	41	41	42	40	39	39
549	SD	SO2812017 1581	38	39	39	38	38	39	39	39
550	SD	SO27120251581	40	40	39	39	39	38	38	0
551	SD	SO28120 1 2581	38	37	37	38	35	35	34	34
552	SD	SO28120 9 2581	33	34	33	32	30	30	30	30
553	SD	SO2812017 2581	30	30	29	29	28	29	29	24
554	SD	SO2812025 2581	26	27	27	27	0	0	0	0
555	SD	SO28120 1 3581	26	26	25	25	25	25	25	25
556	SD	SO28120 9 3581	27	26	26	27	27	28	30	31
557	SD	SO2812017 3581	31	32	34	34	34	34	35	35
558	SD	SO27120253581	34	41	43	43	45	45	57	0
559	SD	SO28120 1 4581	107	175	282	347	591	787	783	1009
560	SD	SO28120 9 4581	1204	1057	[illegible]	1075	1053	1125	1188	1195
561	SD	SO2812017 4581	1204	1195	1180	1171	1182	1196	1185	1198
562	SD	SO2812025 4581	1144	1123	1042	944	943	818	0	0
563	SD	SO28120 1 5581	888	823	790	780	727	712	688	654
564	SD	SO28120 9 5581	536	603	579	531	513	492	468	435
565	SD	SO2812017 5581	408	396	381	366	357	345	333	324
566	SD	SO27120255581	312	309	297	294	300	300	300	0
567	SD	SO28120 1 6581	300	288	279	265	255	240	228	212
568	SD	SO28120 9 6581	204	197	189	183	171	184	180	157
569	SD	SO2812017 6581	151	145	138	140	142	139	133	128
570	SD	SO2812025 6581	125	120	117	114	112	109	0	0
571	SD	SO28120 1 7581	104	100	94	88	85	84	78	74
572	SD	SO28120 9 7581	72	67	62	59	57	55	52	49
573	SD	SO2812017 7581	45	42	40	40	38	38	35	34
574	SD	SO27120257581	33	33	33	32	32	30	28	0
575	SD	SO28120 1 8581	25	24	24	22	24	24	23	22
576	SD	SO28120 9 8581	21	20	18	15	15	14	13	12
577	SD	SO2812017 8581	12	11	10	9	8	8	8	8
578	SD	SO27120258581	8	9	8	6	5	6	5	0
579	SD	SO28120 1 9581	5	5	6	3	3	3	2	2
580	SD	SO28120 9 9581	2	2	13	17	22	33	51	59
581	SD	SO2812017 9581	75	91	119	125	127	133	135	137
582	SD	SO2812025 9581	136	133	128	128	124	118	0	0
583	SD	SO28120 110581	115	116	115	115	105	103	100	98
584	SD	SO28120 910581	96	95	93	91	91	92	91	88
585	SD	SO2812017105 81	88	85	81	91	89	84	78	74
586	SD	SO27120251058 1	88	83	84	56	57	70	67	0
587	SD	SO28120 111581	85	88	70	71	50	58	55	53
588	SD	SO28120 911581	62	72	73	65	59	42	37	25
589	SD	SO2812017115 81	33	30	26	23	15	11	8	7
590	SD	SO2812025115 81	4	3	3	2	2	4	0	0
591	SD	SO28120 112581	4	4	3	2	1	0	0	0
592	SD	SO28120 912581	0	0	0	0	0	0	0	0
593	SD	SO2812017125 81	0	0	0	0	0	0	0	0
594	SD	SO27120251258 1	0	0	0	0	0	0	0	0
595	SD	SO28120 1 1591	0	0	0	0	0	0	0	0
596	SD	SO28120 9 1591	0	0	0	0	0	0	0	0
597	SD	SO2812017 1591	0	0	0	0	0	0	0	0
598	SD	SO27120251591	0	0	0	0	0	0	0	0
599	SD	SO28120 1 2591	0	0	0	0	0	0	0	0

719	SD	5088120 1 8571	288	265	258	252	243	240	234	228
720	SD	5088120 9 8571	218	218	215	212	210	220	233	229
721	SD	50881201 7 8571	224	226	223	221	218	208	205	202
722	SD	508712025 8571	199	200	210	200	202	202	200	0
723	SD	5088120 1 9571	199	197	193	190	198	202	201	201
724	SD	5088120 9 9571	202	205	206	208	211	215	215	220
725	SD	50881201 7 9571	216	211	208	205	199	197	194	193
726	SD	508812025 9571	184	182	177	173	171	168	0	0
727	SD	5088120 110571	168	163	162	178	208	205	202	218
728	SD	5088120 910571	224	235	238	238	244	284	288	284
729	SD	50881201710571	299	317	340	343	345	385	524	488
730	SD	508712025 10571	449	434	445	478	534	524	514	0
731	SD	5088120 111571	432	370	353	231	337	339	280	238
732	SD	5088120 911571	213	223	238	248	282	282	280	287
733	SD	50881201711571	240	223	188	174	158	143	141	143
734	SD	508812025 11571	140	135	136	128	130	122	0	0
735	SD	5088120 112571	128	133	137	137	138	138	137	137
736	SD	5088120 912571	137	138	137	138	138	124	122	118
737	SD	50881201712571	116	116	112	110	110	108	108	110
738	SD	508712025 12571	110	109	108	108	108	103	102	0
739	SD	5088120 1 1581	100	98	97	100	102	103	102	102
740	SD	5088120 9 1581	102	100	101	101	102	103	104	101
741	SD	50881201 7 1581	100	99	98	99	99	98	98	98
742	SD	508712025 1581	100	100	101	101	100	100	99	0
743	SD	5088120 1 2581	98	98	98	97	99	94	94	94
744	SD	5088120 9 2581	92	92	90	91	89	88	86	84
745	SD	50881201 7 2581	88	85	85	85	83	83	82	83
746	SD	508812025 2581	83	82	81	81	0	0	0	0
747	SD	5088120 1 3581	80	79	79	78	77	78	77	77
748	SD	5088120 9 3581	78	78	79	79	78	79	81	82
749	SD	50881201 7 3581	84	87	87	89	92	92	92	92
750	SD	508712025 3581	94	94	98	103	106	107	109	0
751	SD	5088120 1 4581	110	129	212	324	499	672	1008	1330
752	SD	5088120 9 4581	1340	1696	2017	1775	1780	1805	1824	1868
753	SD	50881201 7 4581	1987	2002	2017	2002	1978	1983	1948	1936
754	SD	508812025 4581	1936	1936	1916	1884	1750	1671	0	0
755	SD	5088120 1 5581	1587	1547	1463	1389	1325	1285	1231	1206
756	SD	5088120 9 5581	1167	1117	1083	1028	988	910	880	845
757	SD	50881201 7 5581	808	751	707	687	662	638	623	603
758	SD	508712025 5581	583	569	549	544	524	519	528	0
759	SD	5088120 1 6581	528	528	528	509	494	472	458	430
760	SD	5088120 9 6581	410	385	372	359	348	338	317	305
761	SD	50881201 7 6581	298	294	283	274	263	255	270	284
762	SD	508812025 6581	254	243	241	232	228	222	0	0
763	SD	5088120 1 7581	220	214	207	201	190	180	178	173
764	SD	5088120 9 7581	164	157	153	146	137	132	129	126
765	SD	50881201 7 7581	121	116	110	105	102	101	97	95
766	SD	508712025 7581	93	92	90	89	89	88	88	0
767	SD	5088120 1 8581	84	78	78	75	74	72	75	74
768	SD	5088120 9 8581	73	72	70	68	65	61	59	58
769	SD	50881201 7 8581	56	55	55	53	51	51	49	49
770	SD	508712025 8581	49	49	50	51	48	48	45	0
771	SD	5088120 1 9581	45	45	45	45	45	41	41	40
772	SD	5088120 9 9581	40	39	39	39	57	63	72	89
773	SD	50881201 7 9581	119	132	159	184	221	243	245	254
774	SD	508812025 9581	258	261	260	255	246	243	0	0
775	SD	5088120 110581	239	229	225	226	225	225	209	205
776	SD	5088120 910581	199	197	193	193	189	188	188	187
777	SD	50881201710581	184	178	177	178	168	169	182	173
778	SD	508712025 10581	164	157	145	138	132	127	129	0

779	SD	5088120 111581	150	146	144	147	150	152	118	132
780	SD	5088120 911581	126	123	138	153	158	145	127	105
781	SD	50881201711581	94	93	89	86	79	73	69	64
782	SD	508812025 11581	51	47	43	41	40	40	0	0
783	SD	5088120 112581	40	42	42	43	41	39	38	38
784	SD	5088120 912581	35	34	34	34	34	35	35	35
785	SD	50881201712581	35	35	33	31	32	33	35	35
786	SD	508712025 12581	34	35	35	34	33	32	32	0
787	SD	5088120 1 1591	31	30	28	28	27	25	24	24
788	SD	5088120 9 1591	23	23	23	23	22	21	21	21
789	SD	50881201 7 1591	20	20	19	19	20	20	20	20
790	SD	508712025 1591	20	20	20	21	21	22	22	0
791	SD	5088120 1 2591	22	22	22	22	20	20	20	20
792	SD	5088120 9 2591	20	20	19	19	19	19	18	18
793	SD	50881201 7 2591	17	17	17	17	18	18	18	19
794	SD	508412025 2591	19	20	21	23	0	0	0	0
795	SD	5088120 1 3591	25	27	29	30	32	33	34	38
796	SD	5088120 9 3591	40	41	41	40	39	38	37	37
797	SD	50881201 7 3591	37	37	37	37	37	37	37	38
798	SD	508712025 3591	39	46	46	46	49	48	86	0
799	SD	5088120 1 4591	87	103	107	107	108	107	108	114
800	SD	5088120 9 4591	151	258	304	344	385	412	418	417
801	SD	50881201 7 4591	413	421	440	488	490	499	428	392
802	SD	508812025 4591	365	335	321	308	300	280	0	0
803	SD	5088120 1 5591	274	267	265	257	251	248	244	238
804	SD	5088120 9 5591	238	244	263	274	285	288	295	293
805	SD	50881201 7 5591	285	277	274	268	248	227	218	214
806	SD	508712025 5591	211	208	201	200	182	180	173	0
807	SD	5088120 1 6591	168	161	160	158	156	156	156	153
808	SD	5088120 9 6591	152	153	155	158	160	161	171	218
809	SD	50881201 7 6591	224	244	270	380	412	485	483	504
810	SD	508812025 6591	504	504	493	484	471	465	0	0
811	SD	5088120 1 7591	443	423	408	384	425	574	618	662
812	SD	5088120 9 7591	692	732	732	737	737	707	633	618
813	SD	50881201 7 7591	583	534	473	425	410	381	342	301
814	SD	508712025 7591	275	263	238	225	213	200	180	0
815	SD	5088120 1 8591	178	175	163	165	145	138	136	129
816	SD	5088120 9 8591	125	121	125	128	129	128	119	119
817	SD	50881201 7 8591	117	117	118	126	130	184	219	222
818	SD	508712025 8591	228	241	267	285	439	712	776	0
819	SD	5088120 1 9591	848	839	1004	1063	1068	1068	1083	1083
820	SD	5088120 9 9591	1033	994	929	870	811	742	702	672
821	SD	50881201 7 9591	633	598	564	534	489	488	489	464
822	SD	508812025 9591	441	443	471	482	504	544	0	0
823	SD	5088120 110591	583	613	672	692	707	707	702	702
824	SD	5088120 910591	662	672	668	633	583	583	589	659
825	SD	50881201710591	598	574	583	574	559	549	549	539
826	SD	508712025 10591	514	504	489	482	488	504	504	0
827	SD	5088120 111591	504	504	489	482	484	478	471	489
828	SD	5088120 911591	509	524	524	484	473	439	402	380
829	SD	50881201711591	399	388	371	362	337	330	323	311
830	SD	508812025 11591	298	283	270	260	245	235	0	0
831	SD	5088120 112591	228	218	204	193	184	174	167	161
832	SD	5088120 912591	155	147	138	131	126	117	112	109
833	SD	50881201712591	109	93	90	90	90	88	87	87
834	SD	508712025 12591	85	84	83	81	80	81	81	0
834.2		*** 08AB002 - WOLF R. AT OUTLET OF WOLF LAKE ***								
835	SD	5088120 1 1581	4	4	4	4	4	4	4	4
836	SD	5088120 9 1581	4	4	4	5	4	4	4	4
837	SD	50881201 7 1581	4	4	4	4	4	4	4	4

958	BD	5087120 25 7581	12	12	12	11	11	11	11	0
959	BD	5088120 1 8581	11	10	10	10	10	10	9	9
960	BD	5088120 9 8581	9	9	8	9	9	9	8	8
961	BD	5088120 17 8581	8	8	7	7	7	7	6	6
962	BD	5087120 25 8581	8	8	8	8	8	8	8	0
963	BD	5088120 1 9581	6	6	6	5	5	5	5	5
964	BD	5088120 9 9581	5	5	5	5	5	5	5	5
965	BD	5088120 17 9581	5	7	7	8	10	14	15	19
966	BD	5088120 25 9581	22	27	28	28	30	30	0	0
967	BD	5088120 110581	31	30	30	29	28	28	27	26
968	BD	5088120 810581	27	26	26	24	24	23	23	23
969	BD	5088120 1710581	23	22	22	22	22	22	21	21
970	BD	5087120 2510581	21	22	22	21	20	19	18	0
971	BD	5088120 111581	17	16	16	16	16	16	17	17
972	BD	5088120 811581	17	16	16	14	15	15	14	16
973	BD	5088120 1711581	16	16	17	16	12	11	11	10
974	BD	5088120 2511581	10	9	9	7	6	6	0	0
975	BD	5088120 112581	6	6	6	6	6	6	6	6
976	BD	5088120 812581	6	6	6	4	4	4	4	4
977	BD	5088120 1712581	4	4	4	4	4	4	4	4
978	BD	5087120 2512581	4	4	4	4	4	4	4	0
979	BD	5088120 1 1591	4	4	4	4	4	4	4	3
980	BD	5088120 9 1591	3	3	3	3	3	3	3	3
981	BD	5088120 17 1591	3	3	3	3	2	2	2	2
982	BD	5087120 25 1591	2	2	2	2	2	2	2	0
983	BD	5088120 1 2591	2	2	3	3	3	3	3	3
984	BD	5088120 9 2591	3	2	2	2	2	2	2	2
985	BD	5088120 17 2591	2	2	2	2	2	2	2	2
986	BD	5088120 25 2591	2	2	2	2	0	0	0	0
987	BD	5088120 1 3591	2	2	2	3	3	3	3	3
988	BD	5088120 9 3591	4	4	4	4	4	5	5	5
989	BD	5088120 17 3591	5	5	4	4	4	4	4	4
990	BD	5087120 25 3591	4	4	4	4	4	5	5	0
991	BD	5088120 1 4591	6	6	6	6	10	10	12	13
992	BD	5088120 9 4591	13	12	13	12	13	18	30	36
993	BD	5088120 17 4591	40	43	48	48	48	46	49	53
994	BD	5088120 25 4591	57	57	55	50	46	43	0	0
995	BD	5088120 1 5591	38	38	38	35	33	32	31	31
996	BD	5088120 9 5591	30	29	29	29	28	28	29	31
997	BD	5088120 17 5591	32	33	34	34	34	33	32	32
998	BD	5087120 25 5591	31	29	27	25	25	25	24	0
999	BD	5088120 1 6591	24	23	21	21	20	20	19	19
1000	BD	5088120 9 6591	19	18	18	18	18	18	18	18
1001	BD	5088120 17 6591	18	19	19	20	25	26	29	32
1002	BD	5088120 25 6591	42	48	54	55	59	59	0	0
1003	BD	5088120 1 7591	59	58	57	55	54	52	49	48
1004	BD	5088120 9 7591	46	50	57	72	77	81	86	86
1005	BD	5088120 17 7591	86	86	83	74	72	68	62	55
1006	BD	5087120 25 7591	50	48	45	40	35	32	31	0
1007	BD	5088120 1 8591	26	26	25	23	22	21	21	19
1008	BD	5088120 9 8591	18	17	18	16	15	15	14	16
1009	BD	5088120 17 8591	15	15	15	14	14	14	14	14
1010	BD	5087120 25 8591	15	15	23	26	28	27	26	0
1011	BD	5088120 1 9591	31	34	51	83	91	99	110	117
1012	BD	5088120 9 9591	123	127	127	128	128	121	116	108
1013	BD	5088120 17 9591	102	95	87	82	79	74	70	66
1014	BD	5088120 25 9591	62	58	57	55	53	52	0	0
1015	BD	5088120 110591	52	55	58	59	64	68	72	79
1016	BD	5088120 810591	81	83	83	82	82	80	79	77
1017	BD	5088120 1710591	74	69	68	67	65	63	67	68
1018	BD	5087120 2510591	67	65	64	64	63	60	55	0
1019	BD	5088120 111591	56	56	57	59	59	59	59	56
1020	BD	5088120 811591	54	57	56	55	58	60	61	62
1021	BD	5088120 1711591	56	55	51	47	44	47	46	43
1022	BD	5088120 2511591	42	39	39	38	36	35	0	0
1023	BD	5088120 112591	33	32	30	29	26	26	25	24
1024	BD	5088120 912591	23	22	20	20	18	18	17	18
1025	BD	5088120 1712591	16	16	14	13	13	13	11	11
1026	BD	5087120 2512591	11	11	10	10	10	10	10	0
1026.2		*** 08AC001 - JACKFISH CREEK NEAR LACOREY ***								
1027	BD	5188120 1 1581	2	2	2	2	2	2	2	2
1028	BD	5188120 9 1581	2	2	2	2	2	2	2	2
1029	BD	5188120 17 1581	2	2	2	2	2	2	2	2
1030	BD	5187120 25 1581	2	2	2	2	2	3	3	0
1031	BD	5188120 1 2581	3	3	3	3	3	3	3	3
1032	BD	5188120 9 2581	3	3	3	3	3	3	3	3
1033	BD	5188120 17 2581	3	3	3	3	3	3	3	3
1034	BD	5184120 25 2581	3	3	3	3	3	0	0	0
1035	BD	5188120 1 3581	3	3	3	3	3	3	3	3
1036	BD	5188120 9 3581	3	3	3	3	3	3	3	3
1037	BD	5188120 17 3581	3	3	3	3	3	3	3	3
1038	BD	5187120 25 3581	3	3	3	3	3	3	3	0
1039	BD	5188120 1 4581	3	3	3	3	3	3	3	3
1040	BD	5188120 9 4581	4	6	7	9	10	13	18	30
1041	BD	5188120 17 4581	43	71	105	137	115	172	206	206
1042	BD	5188120 25 4581	213	214	203	185	185	171	0	0
1043	BD	5188120 1 5581	162	158	151	144	135	127	122	117
1044	BD	5188120 9 5581	113	111	106	104	100	95	94	91
1045	BD	5188120 17 5581	88	85	83	79	77	73	71	68
1046	BD	5187120 25 5581	64	62	60	56	56	54	54	0
1047	BD	5188120 1 6581	54	52	51	50	49	48	45	44
1048	BD	5188120 9 6581	42	40	38	36	34	32	31	32
1049	BD	5188120 17 6581	33	36	39	41	44	46	56	76
1050	BD	5188120 25 6581	96	106	120	135	150	162	0	0
1051	BD	5188120 1 7581	170	177	182	185	179	174	156	153
1052	BD	5188120 9 7581	141	135	127	115	113	106	104	102
1053	BD	5188120 17 7581	98	94	92	88	85	81	77	72
1054	BD	5187120 25 7581	68	66	62	62	61	61	60	0
1055	BD	5188120 1 8581	57	55	56	60	61	67	71	73
1056	BD	5188120 9 8581	73	71	69	64	62	57	54	51
1057	BD	5188120 17 8581	46	46	43	42	40	38	37	35
1058	BD	5187120 25 8581	34	33	32	31	30	30	29	0
1059	BD	5188120 1 9581	28	29	30	31	32	32	34	35
1060	BD	5188120 9 9581	35	36	36	35	34	33	32	32
1061	BD	5188120 17 9581	30	30	28	26	28	33	41	52
1062	BD	5188120 25 9581	62	71	74	78	81	81	0	0
1063	BD	5188120 110581	80	78	71	67	63	60	58	52
1064	BD	5188120 810581	50	48	45	43	41	38	36	36
1065	BD	5188120 1710581	34	33	32	31	30	29	28	28
1066	BD	5187120 2510581	27	27	26	24	23	23	22	0
1067	BD	5188120 111581	34	29	28	30	30	32	34	24
1068	BD	5188120 811581	25	26	26	27	28	24	22	21
1069	BD	5188120 1711581	21	20	19	19	20	19	19	18
1070	BD	5188120 2511581	18	17	17	17	17	18	0	0
1071	BD	5188120 112581	18	18	15	15	14	13	12	11
1072	BD	5188120 912581	10	9	8	8	8	8	8	8
1073	BD	5188120 1712581	8	8	8	8	8	8	8	8
1074	BD	5187120 2512581	8	7	7	7	7	7	7	0
1075	BD	5188120 1 1571	7	7	7	7	7	8	8	8
1076	BD	5188120 9 1571	8	8	8	5	5	5	5	4

1197	SD	S168120 17 7581	34	31	27	24	24	22	20	17
1198	SD	S167120 25 7581	16	15	14	13	12	12	11	0
1199	SD	S168120 1 8581	10	10	9	9	8	8	8	7
1200	SD	S168120 9 8581	7	7	7	7	7	7	7	7
1201	SD	S168120 17 8581	7	7	7	7	8	11	13	13
1202	SD	S167120 25 8581	13	14	15	17	25	41	45	0
1203	SD	S168120 1 9581	49	54	58	61	63	63	63	63
1204	SD	S168120 9 9581	59	57	54	50	47	43	40	39
1205	SD	S168120 17 9581	36	34	32	31	28	28	27	26
1206	SD	S168120 25 9581	25	26	27	28	29	31	0	0
1207	SD	L168120 110581	34	35	38	40	41	41	40	40
1208	SD	S168120 910581	39	38	36	36	34	34	33	32
1209	SD	S168120 1710581	32	33	34	33	32	32	32	31
1210	SD	S167120 2510581	30	28	28	28	28	29	29	0
1211	SD	S168120 111581	29	29	29	27	26	27	27	29
1212	SD	S168120 911581	29	30	31	26	27	25	23	22
1213	SD	S168120 1711581	23	23	21	21	19	19	19	18
1214	SD	S168120 2511581	17	16	16	15	14	14	0	0
1215	SD	S168120 112581	13	12	12	11	11	10	10	9
1216	SD	S168120 912581	8	8	8	8	7	7	6	6
1217	SD	S168120 1712581	6	5	5	5	5	5	5	5
1218	SD	S167120 2512581	5	5	5	5	5	5	5	0
1218.2		*** OSAD006 - BEAVER R. AT COLD LAKE RESERVE ***								
1219	SD	S268120 1 1581	70	74	74	75	75	77	75	74
1220	SD	S268120 9 1581	75	75	74	75	74	74	74	75
1221	SD	S268120 17 1581	75	75	74	73	74	74	77	75
1222	SD	S267120 25 1581	79	82	82	85	85	87	91	0
1223	SD	S268120 1 2581	94	94	94	95	94	94	92	92
1224	SD	S268120 9 2581	92	92	92	94	92	92	94	94
1225	SD	S268120 17 2581	94	95	95	93	95	95	95	93
1226	SD	S268120 25 2581	93	92	93	94	94	0	0	0
1227	SD	S268120 1 3581	98	97	96	98	99	98	99	99
1228	SD	S268120 9 3581	101	102	105	103	97	98	102	102
1229	SD	S268120 17 3581	98	98	96	97	97	97	100	104
1230	SD	S267120 25 3581	102	100	99	97	96	94	92	0
1231	SD	S268120 1 4581	91	93	93	96	94	92	95	118
1232	SD	S268120 9 4581	154	200	258	311	368	484	574	1040
1233	SD	S268120 17 4581	1520	2490	3700	4810	4050	8040	7240	7240
1234	SD	S268120 25 4581	7480	7540	7150	6520	6510	6010	0	0
1235	SD	S268120 1 5581	5890	5540	5320	5060	4730	4480	4290	4120
1236	SD	S268120 9 5581	3990	3890	3800	3670	3500	3330	3300	3200
1237	SD	S268120 17 5581	3090	2940	2920	2780	2710	2550	2480	2380
1238	SD	S267120 25 5581	2250	2170	2120	1980	1880	1800	1880	0
1239	SD	S268120 1 6581	1680	1620	1780	1740	1710	1680	1590	1550
1240	SD	S268120 9 6581	1480	1410	1340	1280	1210	1130	1090	1110
1241	SD	S268120 17 6581	1150	1250	1380	1430	1530	1620	1970	2670
1242	SD	S268120 25 6581	3370	3610	4220	4730	5290	5680	0	0
1243	SD	S268120 1 7581	5940	6220	6390	6500	6310	6120	5830	5380
1244	SD	S268120 9 7581	4960	4730	4450	4140	3870	3740	3650	3580
1245	SD	S268120 17 7581	3480	3320	3230	3110	2980	2830	2720	2540
1246	SD	S267120 25 7581	2400	2320	2180	2190	2160	2160	2110	0
1247	SD	S268120 1 8581	2020	1950	1950	2100	2150	2380	2500	2560
1248	SD	S268120 9 8581	2560	2500	2420	2250	2170	2020	1890	1780
1249	SD	S268120 17 8581	1680	1600	1520	1460	1420	1350	1310	1240
1250	SD	S267120 25 8581	1200	1150	1140	1100	1070	1050	1020	0
1251	SD	S268120 1 9581	997	1020	1040	1080	1110	1150	1190	1230
1252	SD	S268120 9 9581	1240	1270	1280	1230	1210	1170	1120	1110
1253	SD	S268120 17 9581	1080	1040	1000	970	986	1150	1440	1840
1254	SD	S268120 25 9581	2170	2480	2590	2740	2840	2860	0	0
1255	SD	S268120 110581	2800	2860	2480	2350	2220	2100	1980	1840
1256	SD	S268120 910581	1740	1830	1580	1500	1430	1350	1320	1250
1257	SD	S268120 1710581	1210	1170	1120	1080	1060	1030	997	978
1258	SD	S267120 2510581	951	831	885	854	814	789	782	0
1259	SD	S268120 111581	1200	1020	974	1040	1070	1110	1180	828
1260	SD	S268120 911581	881	908	927	958	919	832	761	754
1261	SD	S268120 1711581	723	704	679	682	681	658	658	641
1262	SD	S268120 2511581	638	612	586	588	579	565	0	0
1263	SD	S268120 112581	545	546	537	514	488	445	414	380
1264	SD	S268120 912581	357	313	287	279	277	273	273	269
1265	SD	S268120 1712581	263	271	271	269	269	269	269	269
1266	SD	S267120 2512581	255	261	258	259	258	258	258	0
1267	SD	S268120 1 1571	258	258	250	244	228	222	218	218
1268	SD	S268120 9 1571	215	213	187	180	184	173	181	180
1269	SD	S268120 17 1571	148	140	136	134	134	133	133	128
1270	SD	S267120 25 1571	117	114	112	107	102	102	101	0
1271	SD	S268120 1 2571	101	98	99	100	133	139	129	123
1272	SD	S268120 9 2571	118	118	115	110	108	108	103	104
1273	SD	S268120 17 2571	104	98	100	100	98	97	98	88
1274	SD	S268120 25 2571	78	78	78	78	0	0	0	0
1275	SD	S268120 1 3571	74	74	75	75	75	79	84	91
1276	SD	S268120 9 3571	101	115	119	123	120	117	115	115
1277	SD	S268120 17 3571	114	113	112	113	113	114	115	115
1278	SD	S267120 25 3571	119	124	125	125	132	135	152	0
1279	SD	S268120 1 4571	164	178	198	265	328	375	478	612
1280	SD	S268120 9 4571	652	718	691	661	658	648	673	685
1281	SD	S268120 17 4571	682	718	778	825	892	1510	1650	2070
1282	SD	S267120 25 4571	1980	2240	2910	2540	2780	2380	0	0
1283	SD	S268120 1 5571	2300	2140	2020	1930	1830	1780	1690	1650
1284	SD	S268120 9 5571	1600	1560	1480	1480	1430	1370	1310	1330
1285	SD	S268120 17 5571	1310	1300	1280	1280	1210	1200	1110	1080
1286	SD	S267120 25 5571	1080	1030	994	988	951	927	885	0
1287	SD	S268120 1 6571	858	840	810	792	778	765	735	718
1288	SD	S268120 9 6571	704	707	684	682	678	687	658	649
1289	SD	S268120 17 6571	628	601	579	556	545	532	525	519
1290	SD	S267120 25 6571	506	488	468	478	474	471	0	0
1291	SD	S268120 1 7571	471	465	478	481	488	491	494	548
1292	SD	S268120 9 7571	558	558	555	548	536	525	517	512
1293	SD	S268120 17 7571	519	535	530	522	522	519	522	527
1294	SD	S267120 25 7571	558	558	588	579	580	571	558	0
1295	SD	S268120 1 8571	543	535	522	509	491	488	474	481
1296	SD	S268120 9 8571	441	441	434	428	424	444	471	484
1297	SD	S268120 17 8571	481	458	451	448	438	421	414	408
1298	SD	S267120 25 8571	402	404	424	404	409	409	404	0
1299	SD	S268120 1 9571	402	399	390	385	387	409	407	407
1300	SD	S268120 9 9571	409	414	418	421	428	434	438	444
1301	SD	S268120 17 9571	438	428	421	414	402	399	392	390
1302	SD	S268120 25 9571	373	368	359	350	346	338	0	0
1303	SD	S268120 110571	335	330	328	362	416	414	408	438
1304	SD	S268120 910571	454	478	478	478	484	514	543	574
1305	SD	S268120 1710571	604	641	688	694	697	778	858	843
1306	SD	S267120 2510571	908	877	900	986	1080	1080	1040	0
1307	SD	S268120 111571	873	748	713	670	642	585	588	481
1308	SD	S268120 911571	431	451	481	486	530	530	525	519
1309	SD	S268120 1711571	488	451	380	352	320	287	285	288
1310	SD	S267120 2511571	283	273	275	275	263	248	0	0
1311	SD	S268120 112571	284	289	277	277	279	275	277	277
1312	SD	S268120 912571	277	275	277	279	279	280	248	241
1313	SD	S268120 1712571	234	232	227	223	222	218	218	222
1314	SD	S267120 2512571	222	220	218	215	213	208	207	0
1315	SD	S268120 1 1581	202	199	197	202	207	208	207	207

1435	6D	5338120 1 7581	990	1010	1030	1030	1030	1030	1030	1025
1436	6D	5338120 9 7581	1019	1014	1014	1014	1014	1014	1005	997
1437	6D	53381201 7 7581	988	982	975	969	963	945	927	927
1438	6D	533712025 7581	927	927	927	927	927	927	927	0
1439	6D	5338120 1 8581	927	927	927	927	930	945	955	940
1440	6D	5338120 9 8581	925	910	899	889	878	888	853	838
1441	6D	53381201 7 8581	824	809	794	779	764	789	774	778
1442	6D	533712025 8581	764	781	778	778	782	748	735	0
1443	6D	5338120 1 9581	722	685	654	625	625	625	625	625
1444	6D	5338120 9 9581	625	625	625	632	638	645	652	645
1445	6D	53381201 7 9581	638	632	640	650	659	740	740	740
1446	6D	533612025 9581	740	712	685	651	639	648	0	0
1447	6D	5338120 110581	688	686	657	648	640	632	632	632
1448	6D	5338120 910581	632	624	617	609	602	602	602	602
1449	6D	53381201710581	593	585	577	586	578	588	566	578
1450	6D	533712025 10581	577	578	575	575	575	575	566	0
1451	6D	5338120 111581	541	524	507	486	484	473	471	470
1452	6D	5338120 911581	486	466	453	460	457	445	433	421
1453	6D	53381201711581	410	420	430	403	403	403	403	403
1454	6D	533612025 11581	398	389	383	379	376	372	0	0
1455	6D	5338120 112581	369	364	360	356	347	338	332	327
1456	6D	5338120 912581	327	327	327	494	473	452	431	410
1457	6D	53381201712581	390	369	349	331	334	336	343	346
1458	6D	533712025 12581	353	358	363	369	372	374	377	0
1459	6D	5338120 1 1571	380	383	386	389	384	379	374	369
1460	6D	5338120 9 1571	364	359	355	351	346	342	338	335
1461	6D	53381201 7 1571	333	331	329	327	326	324	322	332
1462	6D	533712025 1571	348	348	348	348	348	348	348	0
1463	6D	5338120 1 2571	351	353	355	357	359	362	365	368
1464	6D	5338120 9 2571	371	373	376	376	374	373	372	371
1465	6D	53381201 7 2571	369	369	373	378	383	379	376	373
1466	6D	533612025 2571	371	368	365	362	0	0	0	0
1467	6D	5338120 1 3571	383	383	384	386	387	388	389	371
1468	6D	5338120 9 3571	373	376	378	380	382	384	387	389
1469	6D	53381201 7 3571	390	392	393	394	396	394	393	391
1470	6D	533712025 3571	389	388	387	387	386	385	385	0
1471	6D	5338120 1 4571	384	384	383	382	383	383	383	383
1472	6D	5338120 9 4571	383	383	383	383	383	383	383	388
1473	6D	53381201 7 4571	398	396	394	393	392	390	389	395
1474	6D	533612025 4571	400	406	411	418	424	434	0	0
1475	6D	5338120 1 5571	444	455	465	476	486	497	507	507
1476	6D	5338120 9 5571	507	507	507	507	507	526	544	563
1477	6D	53381201 7 5571	582	585	589	589	592	595	598	602
1478	6D	533712025 5571	605	608	612	603	596	596	595	0
1479	6D	5338120 1 6571	596	603	610	617	625	619	613	608
1480	6D	5338120 9 6571	602	602	602	602	602	602	602	613
1481	6D	53381201 7 6571	625	622	618	615	612	608	605	602
1482	6D	533612025 6571	598	596	596	598	598	598	0	0
1483	6D	5338120 1 7571	596	595	601	606	612	616	620	625
1484	6D	5338120 9 7571	625	625	625	625	625	623	622	620
1485	6D	53381201 7 7571	618	618	618	653	690	733	776	764
1486	6D	533712025 7571	764	764	764	775	785	795	809	0
1487	6D	5338120 1 8571	809	809	809	809	807	805	803	801
1488	6D	5338120 9 8571	801	801	801	801	791	783	774	765
1489	6D	53381201 7 8571	756	750	745	740	735	731	714	698
1490	6D	533712025 8571	680	666	668	665	666	666	684	0
1491	6D	5338120 1 9571	663	661	659	660	672	666	659	659
1492	6D	5338120 9 9571	659	658	656	654	653	652	652	652
1493	6D	53381201 7 9571	631	610	589	588	570	571	572	573
1494	6D	533612025 9571	575	585	586	546	537	528	0	0

1495	6D	5338120 110571	534	541	547	555	562	557	552	548
1496	6D	5338120 910571	548	548	548	544	536	525	514	527
1497	6D	53381201710571	541	555	566	545	521	512	503	495
1498	6D	533712025 10571	487	487	487	487	487	487	487	0
1499	6D	5338120 111571	487	487	487	487	487	487	477	467
1500	6D	5338120 911571	457	446	435	424	424	424	424	424
1501	6D	53381201711571	419	414	410	403	396	389	383	376
1502	6D	533612025 11571	389	382	382	382	382	382	0	0
1503	6D	5338120 112571	362	362	345	330	320	310	313	318
1504	6D	5338120 912571	319	322	309	286	283	306	308	306
1505	6D	53381201712571	308	306	302	296	294	290	247	285
1506	6D	533712025 12571	283	281	279	281	283	286	286	0
1507	6D	5338120 1 1581	290	292	295	297	299	301	304	306
1508	6D	5338120 9 1581	308	310	312	315	317	319	322	312
1509	6D	53381201 7 1581	303	307	312	317	322	327	331	332
1510	6D	533712025 1581	332	332	333	333	334	335	335	0
1511	6D	5338120 1 2581	336	336	337	338	340	341	342	347
1512	6D	5338120 9 2581	352	356	363	369	364	360	356	352
1513	6D	53381201 7 2581	344	354	368	365	371	377	353	389
1514	6D	533612025 2581	389	388	388	389	0	0	0	0
1515	6D	5338120 1 3581	398	407	416	425	435	444	430	415
1516	6D	5338120 9 3581	403	389	386	387	386	385	364	363
1517	6D	53381201 7 3581	363	381	379	378	377	376	374	373
1518	6D	533712025 3581	371	370	368	367	364	362	362	0
1519	6D	5338120 1 4581	362	362	362	362	362	362	362	380
1520	6D	5338120 9 4581	398	415	433	451	456	467	513	540
1521	6D	53381201 7 4581	586	593	618	646	672	697	722	746
1522	6D	533612025 4581	773	799	825	851	864	918	0	0
1523	6D	5338120 1 5581	921	924	927	941	955	967	980	993
1524	6D	5338120 9 5581	1006	1026	1047	1066	1080	1067	1064	1061
1525	6D	53381201 7 5581	1078	1077	1075	1073	1061	1049	1066	1099
1526	6D	533712025 5581	1100	1102	1104	1105	1115	1124	1135	0
1527	6D	5338120 1 6581	1146	1145	1142	1138	1135	1132	1134	1136
1528	6D	5338120 9 6581	1136	1140	1129	1118	1109	1088	1066	1077
1529	6D	53381201 7 6581	1088	1066	1064	1047	1030	1008	988	967
1530	6D	533612025 6581	947	943	938	934	930	926	0	0
1531	6D	5338120 1 7581	922	918	914	910	895	880	865	851
1532	6D	5338120 9 7581	851	851	851	828	806	784	769	754
1533	6D	53381201 7 7581	740	727	715	703	690	678	669	658
1534	6D	533712025 7581	654	650	645	632	618	603	587	0
1535	6D	5338120 1 8581	572	557	543	528	545	562	555	548
1536	6D	5338120 9 8581	541	534	528	524	520	517	514	505
1537	6D	53381201 7 8581	497	488	480	480	480	480	480	465
1538	6D	533712025 8581	448	434	418	403	401	400	398	0
1539	6D	5338120 1 9581	397	395	393	392	390	389	389	389
1540	6D	5338120 9 9581	389	389	382	335	363	371	389	382
1541	6D	53381201 7 9581	376	369	362	355	348	342	338	333
1542	6D	533612025 9581	330	327	324	322	319	317	0	0
1543	6D	5338120 110581	314	312	308	306	306	306	306	304
1544	6D	5338120 910581	301	296	296	292	289	287	287	287
1545	6D	53381201710581	287	287	287	287	285	284	283	278
1546	6D	533712025 10581	287	284	280	287	284	281	247	0
1547	6D	5338120 111581	247	247	247	243	238	238	231	227
1548	6D	5338120 911581	222	218	213	209	204	200	195	195
1549	6D	53381201711581	194	193	193	192	191	191	181	172
1550	6D	533612025 11581	162	152	143	142	141	140	0	0
1551	6D	5338120 112581	138	138	138	138	137	136	136	136
1552	6D	5338120 912581	136	136	136	143	149	155	161	167
1553	6D	53381201712581	173	179	177	176	174	172	170	168
1554	6D	533712025 12581	166	165	163	161	160	158	153	0

1674	SD	930812025 8571	88	87	88	102	104	102	0	0
1675	SD	930812 0 1 7871	109	122	114	106	112	146	152	125
1676	SD	930812 0 9 7871	118	113	107	103	102	105	114	128
1677	SD	930812017 7871	120	107	110	112	114	116	139	134
1678	SD	930712025 7871	126	136	138	118	104	103	105	0
1679	SD	930812 0 1 8571	104	98	93	86	96	91	83	80
1680	SD	930812 0 9 8571	95	91	91	106	126	113	98	100
1681	SD	930812017 8571	98	95	91	83	83	88	86	91
1682	SD	930712025 8571	108	92	87	96	90	90	90	0
1683	SD	930812 0 1 9571	84	83	85	107	98	92	95	98
1684	SD	930812 0 9 9571	99	99	102	105	104	105	96	88
1685	SD	930812017 9571	88	88	83	85	86	86	77	78
1686	SD	930812025 9571	79	74	77	78	78	78	0	0
1687	SD	930812 0 110571	76	103	141	120	90	110	125	128
1688	SD	930812 0 910571	119	107	117	131	142	154	180	188
1689	SD	930812017 10571	186	170	149	203	255	272	205	143
1690	SD	930712025 10571	177	237	305	264	185	78	6	0
1691	SD	930812 0 111571	67	100	127	151	82	3	28	87
1692	SD	930812 0 911571	132	132	140	132	112	105	87	86
1693	SD	930812017 11571	34	34	47	39	85	74	71	82
1694	SD	930812025 11571	86	71	62	51	85	81	0	0
1695	SD	930812 0 112571	79	74	72	88	89	71	70	89
1696	SD	930812 0 912571	70	73	72	90	49	99	98	88
1697	SD	930812017 12571	87	87	88	88	86	84	83	89
1698	SD	930712025 12571	88	87	87	85	85	84	83	0
1699	SD	930812 0 1 1581	83	88	83	91	86	87	88	86
1700	SD	930812 0 9 1581	87	89	89	90	91	86	84	84
1701	SD	930812017 1581	86	87	87	86	86	87	86	89
1702	SD	930712025 1581	89	88	87	87	85	88	88	0
1703	SD	930812 0 1 2581	88	84	83	83	84	85	83	82
1704	SD	930812 0 9 2581	82	84	82	80	48	47	51	83
1705	SD	930812017 2581	83	82	49	46	50	51	51	80
1706	SD	930412025 2581	49	46	46	46	0	0	0	0
1707	SD	930812 0 1 3581	48	48	47	48	48	51	51	50
1708	SD	930812 0 9 3581	52	50	48	51	53	54	56	56
1709	SD	930812017 3581	56	55	59	57	54	54	56	59
1710	SD	930712025 3581	62	67	66	64	63	65	69	0
1711	SD	930812 0 1 4581	204	339	487	820	811	1173	832	1014
1712	SD	930812 0 9 4581	1438	721	393	689	763	783	691	852
1713	SD	930812017 4581	774	737	888	663	887	889	705	715
1714	SD	930812025 4581	687	639	472	401	421	445	0	0
1715	SD	930812 0 1 5581	415	356	367	374	354	372	372	329
1716	SD	930812 0 9 5581	323	286	278	224	228	257	233	184
1717	SD	930812017 5581	173	202	213	189	204	201	189	169
1718	SD	930712025 5581	182	180	183	182	216	221	211	0
1719	SD	930812 0 1 6581	211	163	163	152	145	132	120	113
1720	SD	930812 0 9 6581	116	123	118	118	108	98	110	118
1721	SD	930812017 6581	106	100	84	108	120	115	95	87
1722	SD	930812025 6581	94	93	90	91	91	89	0	0
1723	SD	930812 0 1 7581	83	80	72	88	70	78	68	81
1724	SD	930812 0 9 7581	85	82	84	85	89	81	86	83
1725	SD	930812017 7581	50	46	50	53	51	49	51	51
1726	SD	930712025 7581	51	51	52	52	52	47	38	0
1727	SD	930812 0 1 8581	41	46	46	44	48	50	46	45
1728	SD	930812 0 9 8581	44	42	39	38	37	38	39	38
1729	SD	930812017 8581	40	38	36	37	37	37	38	40
1730	SD	930712025 8581	41	41	37	32	34	37	38	0
1731	SD	930812 0 1 9581	37	38	38	33	32	35	35	34
1732	SD	930812 0 9 9581	34	35	82	89	82	81	113	113
1733	SD	930812017 9581	120	141	178	169	123	123	127	122

1734	SD	930812025 9581	116	107	95	97	100	89	0	0
1735	SD	930812 0 110581	89	100	103	102	78	74	82	84
1736	SD	930812 0 910581	84	88	88	81	85	80	85	77
1737	SD	930812017 10581	78	81	98	98	82	70	82	81
1738	SD	930712025 10581	84	84	95	84	85	89	90	0
1739	SD	930812 0 111581	67	78	81	80	28	45	74	86
1740	SD	930812 0 911581	84	107	95	85	37	18	25	43
1741	SD	930812017 11581	46	45	39	38	23	21	31	31
1742	SD	930812025 11581	28	30	34	35	38	39	0	0
1743	SD	930812 0 112581	39	38	35	31	32	31	30	31
1744	SD	930812 0 912581	31	32	34	34	34	34	34	34
1745	SD	930812017 12581	30	25	30	35	37	35	32	34
1746	SD	930712025 12581	34	31	31	30	28	28	27	0
1747	SD	930812 0 1 1591	27	25	23	21	21	22	21	21
1748	SD	930812 0 9 1591	23	22	20	19	20	20	19	18
1749	SD	930812017 1591	18	17	20	20	20	19	19	20
1750	SD	930712025 1591	20	21	22	22	21	21	21	0
1751	SD	930812 0 1 2591	21	21	18	17	19	20	19	19
1752	SD	930812 0 9 2591	17	17	16	18	16	18	15	15
1753	SD	930812017 2591	17	17	18	18	18	19	19	20
1754	SD	930412025 2591	23	26	27	29	0	0	0	0
1755	SD	930812 0 1 3591	33	33	33	34	35	41	42	38
1756	SD	930812 0 9 3591	37	35	33	34	33	33	34	35
1757	SD	930812017 3591	35	34	35	35	35	36	36	45
1758	SD	930712025 3591	47	44	41	40	90	90	77	0
1759	SD	930812 0 1 4591	80	84	88	80	89	70	122	260
1760	SD	930812 0 9 4591	285	236	215	239	226	176	163	176
1761	SD	930812017 4591	222	282	237	171	108	83	90	83
1762	SD	930812025 4591	92	106	103	92	93	104	0	0
1763	SD	930812 0 1 5591	107	103	96	101	101	96	100	114
1764	SD	930812 0 9 5591	142	150	146	139	137	131	113	104
1765	SD	930812017 5591	106	105	81	83	70	85	90	87
1766	SD	930712025 5591	83	86	87	86	74	89	67	0
1767	SD	930812 0 1 6591	71	75	73	75	77	73	72	79
1768	SD	930812 0 9 6591	78	80	84	85	94	156	155	135
1769	SD	930812017 6591	186	271	313	298	285	242	223	202
1770	SD	930812025 6591	187	174	187	189	150	130	0	0
1771	SD	930812 0 1 7591	130	132	193	415	436	350	345	385
1772	SD	930812 0 9 7591	323	290	290	243	139	153	179	125
1773	SD	930812017 7591	77	81	104	112	74	47	52	77
1774	SD	930712025 7591	84	85	74	87	87	60	89	0
1775	SD	930812 0 1 8591	86	88	85	88	82	87	86	87
1776	SD	930812 0 9 8591	87	75	72	85	84	87	81	81
1777	SD	930812017 8591	85	76	81	183	190	129	112	127
1778	SD	930712025 8591	158	183	359	709	840	481	528	0
1779	SD	930812 0 1 9591	543	515	486	445	415	416	328	275
1780	SD	930812 0 9 9591	247	206	190	154	181	191	176	180
1781	SD	930812017 9591	152	147	133	148	158	151	151	189
1782	SD	930812025 9591	222	246	238	270	212	211	0	0
1783	SD	930812 0 110591	355	349	310	289	267	258	245	232
1784	SD	930812 0 910591	231	207	167	160	199	196	211	242
1785	SD	930812017 10591	256	225	186	182	207	203	189	165
1786	SD	930712025 10591	185	185	185	215	216	202	202	0
1787	SD	930812 0 111591	185	142	160	203	177	235	242	235
1788	SD	930812 0 911591	238	166	129	122	83	97	162	176
1789	SD	930812017 11591	124	117	107	108	123	113	100	94
1790	SD	930812025 11591	92	91	84	80	83	79	0	0
1791	SD	930812 0 112591	73	89	87	84	84	68	64	59
1792	SD	930812 0 912591	54	52	55	49	47	53	58	39
1793	SD	930812017 12591	34	50	54	51	49	51	50	49

1913	6D	9078120 17 8581	212	211	202	198	189	193	199	196
1914	6D	9078120 25 8581	188	180	177	187	184	181	0	0
1915	6D	9078120 1 7581	151	156	151	148	138	127	129	123
1916	6D	9078120 9 7581	116	111	110	104	95	92	91	89
1917	6D	9078120 17 7581	86	83	78	74	72	72	69	65
1918	6D	9077120 25 7581	68	67	66	66	66	66	66	0
1919	6D	9078120 1 8581	62	56	55	54	53	52	56	56
1920	6D	9078120 9 8581	55	54	53	50	47	44	42	41
1921	6D	9078120 17 8581	40	39	40	39	37	37	38	35
1922	6D	9077120 25 8581	36	37	35	39	37	34	33	0
1923	6D	9078120 1 9581	33	32	33	34	34	30	30	29
1924	6D	9078120 9 9581	28	26	29	29	46	53	62	60
1925	6D	9078120 17 9581	110	118	144	187	210	214	213	219
1926	6D	9078120 25 9581	214	205	201	196	185	181	0	0
1927	6D	9078120 110581	176	167	164	167	166	167	154	151
1928	6D	9078120 910581	144	143	139	143	140	138	139	141
1929	6D	9078120 1710581	138	133	132	131	141	142	139	130
1930	6D	9077120 2510581	122	112	100	95	90	87	91	0
1931	6D	9078120 111581	116	112	112	116	119	116	63	97
1932	6D	9078120 911581	91	87	102	126	124	116	86	72
1933	6D	9078120 1711581	60	55	54	56	53	50	37	33
1934	6D	9078120 2511581	30	26	26	26	27	27	0	0
1935	6D	9078120 112581	29	31	32	33	31	29	28	28
1936	6D	9078120 912581	24	24	24	25	25	26	26	27
1937	6D	9078120 1712581	27	27	28	23	24	25	27	27
1938	6D	9077120 2512581	27	27	27	25	25	24	23	0
1939	6D	9078120 1 1591	23	22	21	20	19	18	17	17
1940	6D	9078120 9 1591	16	16	17	17	16	16	16	15
1941	6D	9078120 17 1591	15	15	14	14	15	15	15	15
1942	6D	9077120 25 1591	15	16	16	16	17	17	17	0
1943	6D	9078120 1 2591	17	17	17	17	15	15	15	15
1944	6D	9078120 9 2591	15	15	14	14	14	14	13	13
1945	6D	9078120 17 2591	12	12	13	13	14	14	14	15
1946	6D	9078120 25 2591	15	16	17	19	0	0	0	0
1947	6D	9078120 1 3591	20	22	25	25	26	27	27	31
1948	6D	9078120 9 3591	32	33	33	32	30	29	27	27
1949	6D	9078120 17 3591	27	26	26	26	26	26	26	29
1950	6D	9077120 25 3591	30	36	39	40	40	40	79	0
1951	6D	9078120 1 4591	78	91	95	95	85	85	81	88
1952	6D	9078120 9 4591	125	229	276	318	338	376	358	344
1953	6D	9078120 17 4591	330	333	361	385	389	370	325	284
1954	6D	9078120 25 4591	248	217	208	206	206	192	0	0
1955	6D	9078120 1 5591	183	190	190	185	183	182	180	174
1956	6D	9078120 9 5591	176	184	203	215	228	231	236	230
1957	6D	9078120 17 5591	219	208	205	195	176	158	151	148
1958	6D	9077120 25 5591	147	147	146	148	131	129	123	0
1959	6D	9078120 1 6591	120	113	116	115	114	116	117	114
1960	6D	9078120 9 6591	114	116	118	119	123	124	134	181
1961	6D	9078120 17 6591	187	205	231	319	360	411	424	439
1962	6D	9078120 25 6591	417	405	381	358	350	344	0	0
1963	6D	9078120 1 7591	322	304	289	280	313	467	516	564
1964	6D	9078120 9 7591	597	630	594	568	578	540	457	442
1965	6D	9078120 17 7591	406	357	303	273	261	241	213	187
1966	6D	9077120 25 7591	173	164	143	143	140	134	127	0
1967	6D	9078120 1 8591	119	121	112	107	99	97	94	90
1968	6D	9078120 9 8591	86	86	91	95	98	98	90	89
1969	6D	9078120 17 8591	86	85	86	97	101	186	191	194
1970	6D	9077120 25 8591	198	210	220	242	385	657	718	0
1971	6D	9078120 1 9591	781	868	896	882	901	884	866	852
1972	6D	9078120 9 9591	780	732	687	606	547	493	463	447

1973	6D	9078120 17 9591	423	403	385	365	357	334	328	318
1974	6D	9078120 25 9591	312	323	354	378	398	438	0	0
1975	6D	9078120 110791	476	499	554	571	576	567	554	540
1976	6D	9078120 910791	515	502	488	484	424	419	407	401
1977	6D	9078120 1710791	407	431	443	437	424	414	411	399
1978	6D	9077120 2510791	376	359	367	380	356	380	383	0
1979	6D	9078120 111591	384	386	382	341	383	354	350	379
1980	6D	9078120 911591	396	407	420	380	353	316	278	251
1981	6D	9078120 1711591	280	282	285	285	246	234	228	222
1982	6D	9078120 2511591	209	202	190	182	170	164	0	0
1983	6D	9078120 112591	157	151	141	134	127	120	115	112
1984	6D	9078120 912591	109	103	96	91	87	80	77	76
1985	6D	9078120 1712591	78	63	62	63	63	61	64	65
1986	6D	9077120 2512591	63	62	62	60	59	60	60	0
1986 .2		*** NET LAKE EVAPORATION STA 600 ***								
1987	6D	8008120 1 1561	-33	-33	178	877	346	-33	72	-33
1988	6D	8008120 9 1561	-33	136	666	-33	30	-33	30	264
1989	6D	8008120 17 1561	-33	-33	-33	-33	-33	-33	-33	1851
1990	6D	8007120 25 1561	1746	30	-33	-33	-33	-33	-33	0
1991	6D	8008120 1 2561	-55	-55	-55	474	-55	-55	-55	-55
1992	6D	8008120 9 2561	156	156	156	114	50	50	6	114
1993	6D	8008120 17 2561	-55	-55	-55	-55	1446	156	-55	-55
1994	6D	8004120 25 2561	-55	-55	6	-55	-55	0	0	0
1995	6D	8008120 1 3561	-95	-95	2361	803	116	-95	-95	-95
1996	6D	8008120 9 3561	-95	-95	-32	10	-95	-95	709	-95
1997	6D	8008120 17 3561	-95	-95	-95	74	-95	-95	74	-95
1998	6D	8007120 25 3561	815	540	160	-95	74	10	-95	0
1999	6D	8008120 1 4561	-257	-257	-257	60	-257	-257	-257	-257
2000	6D	8008120 9 4561	60	-257	-257	-257	-257	-257	-257	-257
2001	6D	8008120 17 4561	-257	-257	-257	-257	-257	-257	-46	-152
2002	6D	8008120 25 4561	-257	-257	-257	-257	-257	-257	0	0
2003	6D	8008120 1 5561	-408	-408	-408	-408	-408	-408	-408	-408
2004	6D	8008120 9 5561	-408	-408	-134	-408	120	-408	-408	-408
2005	6D	8008120 17 5561	-408	-408	-408	-408	-409	-409	-409	-348
2006	6D	8007120 25 5561	-408	-409	-408	-408	1750	-408	-408	0
2007	6D	8008120 1 6561	-677	-677	-677	-402	-677	-677	-677	-677
2008	6D	8008120 9 6561	-677	-677	-677	-677	-677	-677	508	3081
2009	6D	8008120 17 6561	-614	-677	-677	720	4318	3187	-677	3133
2010	6D	8008120 25 6561	-677	-677	288	-677	783	339	0	0
2011	6D	8008120 1 7561	-780	-780	-780	-780	-780	120	-483	-780
2012	6D	8008120 9 7561	-780	-463	-780	4978	-611	-780	-357	-145
2013	6D	8008120 17 7561	-780	-780	-780	-780	-780	-780	-780	-675
2014	6D	8007120 25 7561	3623	-780	2228	289	-780	-780	-780	0
2015	6D	8008120 1 8561	-485	-802	1082	2415	-802	-802	-802	-802
2016	6D	8008120 9 8561	-802	-802	-802	-802	-421	-802	-802	-802
2017	6D	8008120 17 8561	-802	-802	-802	-187	-802	-802	-802	65
2018	6D	8007120 25 8561	-833	-802	870	-802	-802	-802	-485	0
2019	6D	8008120 1 9561	2184	1009	-789	-484	-789	-788	-788	-789
2020	6D	8008120 9 9561	-788	-789	-789	-558	-788	-800	-789	-789
2021	6D	8008120 17 9561	-789	-789	-789	-789	6280	-789	-789	-789
2022	6D	8008120 25 9561	-789	-789	-789	-789	-789	-789	0	0
2023	6D	8008120 110561	-483	702	-483	-483	-483	-483	-483	-483
2024	6D	8008120 910561	-483	-483	-483	-483	-483	-483	-483	-483
2025	6D	8008120 1710561	-483	-483	-483	-483	-483	-483	-483	-483
2026	6D	8007120 2510561	279	46	46	-483	-483	-314	-483	0
2027	6D	8008120 111561	-88	-88	-88	-88	891	-88	-88	-88
2028	6D	8008120 911561	-25	-88	-88	904	293	-25	-88	-88
2029	6D	8008120 1711561	1309	293	-88	-88	17	-88	-88	-88
2030	6D	8008120 2511561	-88	-88	-88	-88	-88	-88	0	0
2031	6D	8008120 112561	84	-41	581	170	-41	-41	-41	832

2152	SD	8008120 9 5591	-190	7220	-575	-147	-575	2880	-575	827
2153	SD	8008120171 5591	815	-575	-575	-575	-575	-190	-575	-575
2154	SD	8008120251 5591	-575	-575	-575	-513	22	-575	0	0
2155	SD	8008120 1 7591	-775	8303	-188	519	-775	-143	-481	-775
2156	SD	8008120 9 7591	407	-775	-775	-775	-355	-775	-775	-775
2157	SD	8008120171 7591	-775	-775	-775	-775	2018	-775	-775	-775
2158	SD	8007120251 7591	-775	-587	-587	-503	-775	-775	-775	0
2159	SD	8008120 1 8591	-800	-800	-38	-589	-800	-800	-800	-208
2160	SD	8008120 9 8591	-800	3455	173	-800	-800	-800	-371	279
2161	SD	8008120171 8591	-800	554	-737	703	2311	218	-800	-548
2162	SD	8007120251 8591	-208	3942	1401	1020	-800	-800	218	0
2163	SD	8008120 1 9591	-788	-788	-387	-788	-788	523	-788	-8
2164	SD	8008120 9 9591	-788	-788	-788	-788	-788	-788	-782	-788
2165	SD	8008120171 9591	-788	458	-589	-589	-483	-583	-788	-788
2166	SD	8008120251 9591	-387	1118	-387	-788	-387	-788	0	0
2167	SD	8008120 110591	153	-482	-482	-377	-418	-482	-482	-482
2168	SD	8008120 910591	3487	840	-482	-418	-377	-207	-482	-482
2169	SD	8008120171 0591	-482	-482	-482	-482	-482	-418	-482	-482
2170	SD	8007120251 0591	-482	-482	4	-271	-313	-377	-482	0
2171	SD	8008120 111591	718	283	-88	-88	-88	335	-88	-88
2172	SD	8008120 911591	-88	-88	-88	-88	17	-88	-88	-88
2173	SD	8008120171 1591	398	-88	-88	-88	885	-88	-88	885
2174	SD	8008120251 1591	-88	-88	-88	-88	-88	-88	0	0
2175	SD	8008120 112591	-41	-41	-41	22	84	-41	-41	-41
2176	SD	8008120 912591	-41	-41	-41	-41	-41	22	-41	-41
2177	SD	8008120171 2591	-41	-41	-41	-41	-41	-41	-41	-41
2178	SD	8007120251 2591	857	763	170	-41	-41	-41	-41	0
2178.2		*** COMPUTED NET LOCAL 131 TO PRIMROSE L ***								
2179	SD	1318120 1 1561	-1	732	577	700	723	551	142	-3
2180	SD	1318120 9 1561	-3	139	-31	145	142	145	281	133
2181	SD	1318120171 1561	284	295	146	444	445	445	447	375
2182	SD	1317120251 1561	380	448	452	7	-142	5	4	0
2183	SD	1318120 1 2561	4	4	3	279	301	301	302	303
2184	SD	1318120 9 2561	444	295	148	149	152	152	153	149
2185	SD	1318120171 2561	155	155	156	156	97	148	155	156
2186	SD	1314120251 2561	7	155	5	8	154	0	0	0
2187	SD	1318120 1 3561	7	155	58	277	147	305	305	157
2188	SD	1318120 9 3561	305	157	155	153	157	157	126	157
2189	SD	1318120171 3561	305	307	308	301	309	309	303	310
2190	SD	1317120251 3561	128	137	151	162	155	158	460	0
2191	SD	1318120 1 4561	468	469	470	458	324	474	474	475
2192	SD	1318120 9 4561	482	326	175	172	320	158	164	287
2193	SD	1318120171 4561	131	95	200	11	193	1811	1574	1814
2194	SD	1318120251 4561	1848	1851	1895	1857	493	517	0	0
2195	SD	1318120 1 5561	542	548	553	564	575	589	847	771
2196	SD	1318120 9 5561	773	723	772	786	700	729	648	738
2197	SD	1318120171 5561	745	751	785	427	430	353	439	441
2198	SD	1317120251 5561	448	536	288	291	207	1719	1812	0
2199	SD	1318120 1 6561	1748	1842	343	334	345	-409	-411	-415
2200	SD	1318120 9 6561	-418	570	784	580	583	588	545	545
2201	SD	1318120171 6561	354	352	347	2892	2883	2778	2940	4085
2202	SD	1318120251 6561	4155	4306	1128	1154	1089	1105	0	0
2203	SD	1318120 1 7561	1882	1758	1785	433	443	418	454	148
2204	SD	1318120 9 7561	95	153	507	292	512	523	-97	-43
2205	SD	1318120171 7561	-66	111	42	109	110	-695	-704	499
2206	SD	1317120251 7561	335	508	395	469	510	509	510	0
2207	SD	1318120 1 8561	503	517	443	386	1115	1112	1175	-495
2208	SD	1318120 9 8561	-508	-513	-247	-179	-284	-182	-520	-525
2209	SD	1318120171 8561	-464	-537	-544	-578	-580	778	782	885
2210	SD	1317120251 8561	850	256	189	321	-487	-494	-447	0
2211	SD	1318120 1 9561	-559	-2135	-2035	-2064	352	360	359	358
2212	SD	1318120 9 9561	358	357	358	938	867	950	953	-208
2213	SD	1318120171 9561	-210	-130	1043	1216	862	6094	417	401
2214	SD	1318120251 9561	389	-1506	-1458	-1508	-1520	1070	0	0
2215	SD	1318120 110561	987	1119	-415	-414	-331	-332	339	342
2216	SD	1318120 910561	345	-324	-244	-330	-250	338	336	339
2217	SD	1318120171 0561	-415	-337	-340	-427	1182	1253	-1426	1164
2218	SD	1317120251 0561	218	227	227	333	334	327	-1092	0
2219	SD	1318120 111561	-1139	-1142	-1151	-660	-794	-672	72	188
2220	SD	1318120 911561	80	81	-5	-30	-26	-787	-768	-774
2221	SD	1318120171 1561	-782	1045	1086	-2034	211	217	217	217
2222	SD	1318120251 1561	-370	-374	-293	-129	-47	-132	0	0
2223	SD	1318120 112561	-83	-218	-181	-147	-560	-564	-511	-597
2224	SD	1318120 912561	128	147	185	14719	-1511	-1493	-1506	-1518
2225	SD	1318120171 2561	-1446	-1542	-1470	-1573	631	589	610	613
2226	SD	1317120251 2561	615	614	622	709	481	378	455	0
2227	SD	1318120 1 1571	484	486	468	470	-218	-212	-267	-207
2228	SD	1318120 9 1571	-210	-213	-132	-134	-230	-139	-140	-58
2229	SD	1318120171 1571	-108	-107	-108	-111	36	-111	-112	1873
2230	SD	1317120251 1571	1726	200	181	200	200	200	200	0
2231	SD	1318120 1 2571	453	371	389	389	373	455	460	463
2232	SD	1318120 9 2571	480	382	468	125	133	130	132	131
2233	SD	1318120171 2571	47	209	580	623	638	-117	-47	-50
2234	SD	1314120251 2571	48	-38	-53	-40	0	0	0	0
2235	SD	1318120 1 3571	297	207	291	381	289	299	300	382
2236	SD	1318120 9 3571	374	428	379	388	389	390	478	393
2237	SD	1318120171 3571	312	395	313	314	351	35	146	62
2238	SD	1317120251 3571	50	143	142	225	141	140	223	0
2239	SD	1318120 1 4571	145	228	143	224	222	221	214	212
2240	SD	1318120 9 4571	212	208	210	213	214	214	214	717
2241	SD	1318120171 4571	804	138	133	124	127	20	87	538
2242	SD	1318120251 4571	594	671	571	786	671	1025	0	0
2243	SD	1318120 1 5571	1040	1129	1085	1104	1081	1184	1098	265
2244	SD	1318120 9 5571	266	267	268	283	238	1762	1831	1889
2245	SD	1318120171 5571	1498	564	654	321	575	577	582	629
2246	SD	1317120251 5571	562	588	675	-412	-272	321	336	0
2247	SD	1318120 1 6571	348	938	938	943	1023	-136	-139	-58
2248	SD	1318120 9 6571	-144	308	358	348	356	356	357	1280
2249	SD	1318120171 6571	1371	51	38	117	118	3	10[illegible]	88
2250	SD	1318120251 6571	-23	182	324	343	354	359	0	0
2251	SD	1318120 1 7571	332	338	718	783	874	622	674	725
2252	SD	1318120 9 7571	380	377	314	380	381	214	265	213
2253	SD	1318120171 7571	87	377	380	3318	3221	3298	3332	-336
2254	SD	1317120251 7571	480	480	388	1198	1205	1195	1205	0
2255	SD	1318120 1 8571	490	481	481	470	357	232	335	354
2256	SD	1318120 9 8571	489	468	375	464	-184	-86	-132	-134
2257	SD	1318120171 8571	-139	57	122	113	104	181	-710	-925
2258	SD	1317120251 8571	-847	-735	365	410	410	410	122	0
2259	SD	1318120 1 9571	325	241	227	2047	-170	-95	-237	386
2260	SD	1318120 9 9571	408	308	237	236	318	317	304	392
2261	SD	1318120171 9571	-1363	-1374	-1366	-1398	512	426	439	440
2262	SD	1318120251 9571	525	-481	-402	-481	-413	-416	0	0
2263	SD	1318120 110571	822	856	781	5784	645	-91	-98	-8
2264	SD	1318120 910571	325	325	325	325	-582	-608	-613	1393
2265	SD	1318120171 0571	1484	1481	1413	-1805	-1740	-472	-463	-387
2266	SD	1317120251 0571	-381	277	277	288	272	280	273	0
2267	SD	1318120 111571	282	287	355	270	270	266	-574	-571
2268	SD	1318120 911571	-575	-572	-588	-581	223	233	80	191
2269	SD	1318120171 1571	-184	-208	-108	-355	-354	-384	-284	-398
2270	SD	1318120251 1571	-373	-377	185	205	207	172	0	0

2390	80	1337120251 8581	282	356	174	178	251	1212	1278	0
2391	80	1338120 1 8581	1218	1267	201	212	203	-243	-248	-248
2392	80	1338120 9 8581	-390	438	502	445	447	481	493	582
2393	80	1338120171 8581	213	204	204	2133	2208	2208	2081	3134
2394	80	1338120251 8581	2981	3071	829	788	832	818	0	0
2395	80	1338120 1 7581	1170	1223	1230	285	272	311	300	59
2396	80	1338120 9 7581	20	82	319	521	333	330	-83	-40
2397	80	1338120171 7581	-112	22	-18	31	31	-552	-558	319
2398	80	1337120251 7581	468	320	425	358	321	320	321	0
2399	80	1338120 1 8581	331	321	385	427	784	782	801	-414
2400	80	1338120 9 8581	-420	-425	-232	-183	-220	-185	-430	-423
2401	80	1338120171 8581	-368	-442	-447	-432	-459	510	513	487
2402	80	1337120251 8581	573	132	188	179	-408	-411	-387	0
2403	80	1338120 1 9581	-271	-1488	-1524	-1528	211	211	209	208
2404	80	1338120 9 9581	208	208	208	642	578	648	847	-201
2405	80	1338120171 9581	-203	-184	705	830	1012	4382	251	240
2406	80	1338120251 9581	231	-1141	-1108	-1142	-1182	725	0	0
2407	80	1338120 110581	880	849	-335	-335	-275	-275	210	213
2408	80	1338120 910581	215	-289	-211	-274	-218	208	209	210
2409	80	1338120171 0581	-338	-279	-281	-364	807	873	-1087	808
2410	80	1337120251 0581	170	182	182	206	207	213	-828	0
2411	80	1338120 111581	-826	-828	-835	-479	-509	-488	51	120
2412	80	1338120 911581	80	97	-5	14	4	-583	-857	-882
2413	80	1338120171 1581	-859	779	771	-1474	158	158	158	158
2414	80	1338120251 1581	-289	-272	-213	-95	-35	-97	0	0
2415	80	1338120 112581	-35	-181	-82	-88	-409	-411	-373	-375
2416	80	1338120 912581	175	184	131	10858	-1080	-1084	-1094	-1102
2417	80	1338120171 2581	-1080	-1120	-1087	-1142	458	424	439	441
2418	80	1337120251 2581	442	448	447	510	331	271	340	0
2419	80	1338120 1 1571	334	335	337	338	-129	-138	-85	-152
2420	80	1338120 9 1571	-184	-156	-97	-98	-151	-102	-103	-44
2421	80	1338120171 1571	-79	-75	-80	-79	28	-82	-83	1210
2422	80	1337120251 1571	1280	143	180	143	143	143	143	0
2423	80	1338120 1 2571	334	285	258	270	288	328	329	331
2424	80	1338120 9 2571	336	273	335	100	93	94	92	91
2425	80	1338120171 2571	30	184	394	487	458	-84	-14	-14
2426	80	1334120251 2571	31	-28	-19	-33	0	0	0	0
2427	80	1338120 1 3571	207	182	213	268	208	209	209	270
2428	80	1338120 9 3571	280	389	280	273	274	275	337	277
2429	80	1338120171 3571	218	279	319	219	322	82	98	37
2430	80	1337120251 3571	38	95	95	156	94	94	154	0
2431	80	1338120 1 4571	88	148	87	145	144	143	142	138
2432	80	1338120 9 4571	138	134	135	137	138	138	138	802
2433	80	1338120171 4571	865	81	79	83	75	-3	83	883
2434	80	1338120251 4571	413	469	398	530	469	728	0	0
2435	80	1338120 1 5571	730	814	746	857	763	637	772	188
2436	80	1338120 9 5571	189	170	171	186	200	1285	1378	1360
2437	80	1338120171 5571	1352	388	490	209	393	394	398	495
2438	80	1337120251 5571	423	408	489	-322	-183	232	220	0
2439	80	1338120 1 6571	212	838	843	846	716	-139	-141	-82
2440	80	1338120 9 6571	-145	258	217	227	218	218	218	887
2441	80	1338120171 6571	852	107	-18	45	44	5	43	80
2442	80	1338120251 6571	19	98	248	232	223	219	0	0
2443	80	1338120 1 7571	241	238	574	521	580	538	498	523
2444	80	1338120 9 7571	232	224	278	222	223	102	170	101
2445	80	1338120171 7571	207	220	243	2347	2330	2388	2388	-298
2446	80	1337120251 7571	280	280	344	818	818	847	843	0
2447	80	1338120 1 8571	298	299	298	317	202	308	218	200
2448	80	1338120 9 8571	297	297	398	318	-190	-72	-147	-184
2449	80	1338120171 8571	-158	-15	31	36	38	75	-547	-478

2450	80	1337120251 8571	-525	-488	261	241	241	241	224	0
2451	80	1338120 1 9571	160	119	129	1488	-178	-117	-133	258
2452	80	1338120 9 9571	236	188	117	115	175	174	319	241
2453	80	1338120171 9571	-1042	-1051	-1058	-1088	329	273	283	283
2454	80	1337120251 9571	324	-403	-347	-411	-384	-358	0	0
2455	80	1338120 110571	551	571	600	5405	895	-89	-88	-39
2456	80	1338120 910571	202	202	202	202	-528	-473	-478	978
2457	80	1338120171 0571	1041	1045	990	-1188	-1227	-348	-388	-315
2458	80	1337120251 0571	-317	187	187	171	183	174	184	0
2459	80	1338120 111571	183	187	302	190	189	180	-412	-419
2460	80	1338120 911571	-422	-482	-469	-499	173	173	289	202
2461	80	1338120171 1571	-138	-122	-74	-283	-285	-283	-205	-248
2462	80	1337120251 1571	-277	-278	182	143	143	175	0	0
2463	80	1338120 112571	181	223	-888	-1010	-931	-952	446	489
2464	80	1338120 912571	470	450	-1274	-1278	-1285	2598	121	122
2465	80	1338120171 2571	122	145	-289	-271	-292	-300	-206	-102
2466	80	1337120251 2571	-85	-89	-104	326	345	436	328	0
2467	80	1338120 1 3571	330	331	440	333	334	335	443	337
2468	80	1338120 9 3571	338	356	352	481	343	342	451	-350
2469	80	1338120171 3571	-848	555	885	884	785	888	882	255
2470	80	1337120251 3571	135	132	243	137	283	303	152	0
2471	80	1338120 1 4571	219	135	212	233	281	200	198	442
2472	80	1338120 9 4571	444	847	457	515	-184	-98	-97	-93
2473	80	1338120171 4571	-101	505	481	576	513	515	516	520
2474	80	1334120251 4571	180	180	158	158	0	0	0	0
2475	80	1338120 1 5571	719	707	721	724	783	774	-531	-872
2476	80	1338120 9 5571	-889	-889	95	95	95	94	94	95
2477	80	1338120171 5571	154	32	31	98	100	92	25	88
2478	80	1337120251 5571	27	88	90	25	24	40	187	0
2479	80	1338120 1 6571	137	138	152	125	115	107	91	1188
2480	80	1338120 9 6571	1174	1117	1157	1152	1134	1280	1704	1775
2481	80	1338120171 6571	1735	1828	1732	1813	1788	1476	1422	1480
2482	80	1337120251 6571	1448	1501	1520	1525	1844	2000	0	0
2483	80	1338120 1 7571	415	485	481	1000	1035	918	874	980
2484	80	1338120 9 7571	980	1335	1418	1425	1484	359	359	259
2485	80	1338120171 7571	308	309	310	310	797	818	858	488
2486	80	1337120251 7571	477	843	530	488	983	1011	1089	0
2487	80	1338120 1 8571	1081	255	259	218	288	271	933	538
2488	80	1338120 9 8571	539	539	-150	-100	-104	-148	-17	-71
2489	80	1338120171 8571	-128	-108	840	-384	-429	-831	-840	-849
2490	80	1334120251 8571	-809	153	151	263	188	202	0	0
2491	80	1338120 1 9571	153	201	150	151	-388	-394	-400	-357
2492	80	1338120 9 9571	319	319	319	-801	-761	-770	-438	-443
2493	80	1338120171 9571	-402	-388	-318	-320	-273	-282	-308	-383
2494	80	1337120251 9571	-49	-2	-43	-853	-821	-888	-748	0
2495	80	1338120 1 0571	-703	-708	-843	-873	1217	1238	-227	-223
2496	80	1338120 9 0571	-207	-238	-172	-85	-80	8	-2	-388
2497	80	1338120171 0571	-311	-378	-318	170	194	185	185	-747
2498	80	1337120251 0571	-889	-780	-827	-773	17	138	10	0
2499	80	1338120 1 1571	131	12	11	71	10	89	130	130
2500	80	1338120 9 1571	180	130	-1808	-1457	8128	1253	1214	-298
2501	80	1338120171 1571	-188	-308	-308	-318	-320	-282	-288	-178
2502	80	1337120251 1571	-218	-228	-229	-122	-230	-124	0	0
2503	80	1338120 112571	-214	-112	-221	-222	100	100	118	-118
2504	80	1338120 912571	-223	-224	-228	-227	-226	-121	84	84
2505	80	1338120171 2571	84	104	104	84	-122	-18	-18	-770
2506	80	1337120251 2571	-773	-237	-348	-238	-240	-241	-380	0
2507	80	1338120 1 3571	84	84	101	-337	-338	-338	-341	-342
2508	80	1338120 9 3571	-482	-348	-458	-352	-481	-358	-453	77
2509	80	1338120171 3571	-33	-33	75	-22	-34	74	-1004	-889

APPENDIX B

VERIFICATION PLOTS - BEAVER RIVER AT COLD LAKE

This Appendix contains graphical output from the SSARR model for the Beaver River at Cold Lake.

Three hydrographs for the Beaver River at Cold Lake are presented in this Appendix for the period 1956 to 1980:

1. Computed streamflows - these flows were computed by routing the local area runoff flows through the lake and channel system to the downstream location, as described in the text.

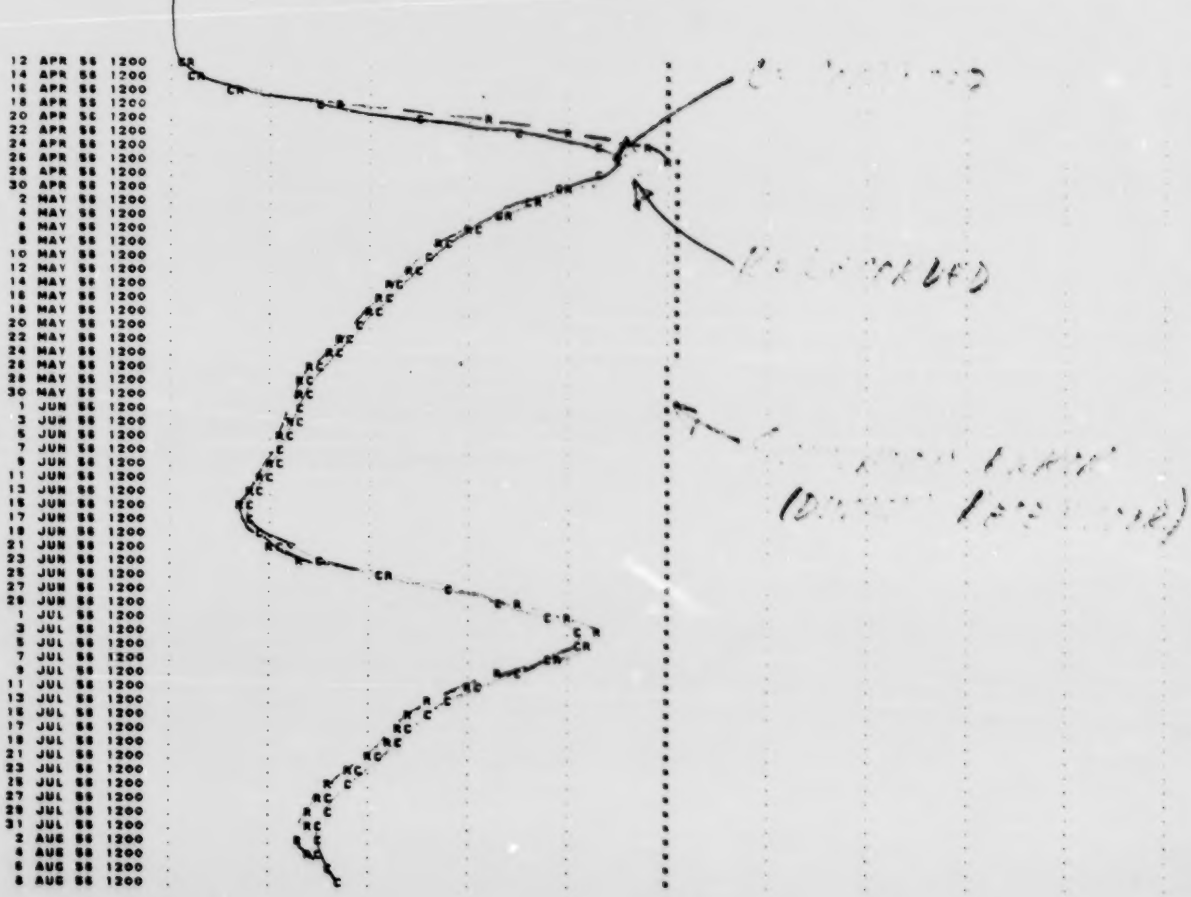
2. Recorded streamflows - from Water Survey of Canada records.

3. Simulation error - the cumulative difference between the recorded and computed streamflows is plotted as inches of runoff over the basin. The simulation error is calculated with the dummy reservoirs as described in the text. This graph indicates that the computed streamflows exceeded the recorded streamflows by about 1.5 inches over the 25-year period, or 2.6% of the recorded runoff.

PLOT CHARACTER	STATION NAME	STATION NUMBER	CONTROL
C	CALC BEAVER RIVER FLOW AT COLD LAKE	726.0	0
R	BEAVER R AT COLD LAKE 08AD008	52.6	0
*	DUMMY RES (DIFF) AT BEAVER RIVER AT COLD LA	726.2	8

FLOW CFS: 0, 1500, 3000, 4500, 6000, 7500, 9000, 10500, 12000, 13500, 15000

ELEV FT: -5, -4, -3, -2, -1, -0, 1, 2, 3, 4, 5



```
10 AUG 56 1200                    C
12 AUG 56 1200                  RC
14 AUG 56 1200                RC
16 AUG 56 1200               RC
18 AUG 56 1200              RC
20 AUG 56 1200             RC
22 AUG 56 1200            RC
24 AUG 56 1200          RC
26 AUG 56 1200          RC
28 AUG 56 1200         RC
30 AUG 56 1200         RC
 1 SEP 56 1200         C
 3 SEP 56 1200         RC
 5 SEP 56 1200         RC
 7 SEP 56 1200          C
 9 SEP 56 1200          RC
11 SEP 56 1200          RC
13 SEP 56 1200          C
15 SEP 56 1200         RC
17 SEP 56 1200         C
19 SEP 56 1200         C
21 SEP 56 1200         RC
23 SEP 56 1200             C
25 SEP 56 1200               CR
27 SEP 56 1200                 CR
29 SEP 56 1200                   CR
 1 OCT 56 1200                   CR
 3 OCT 56 1200                 C
 5 OCT 56 1200               C
 7 OCT 56 1200             C
 9 OCT 56 1200            C
11 OCT 56 1200           C
13 OCT 56 1200          C
15 OCT 56 1200         C
17 OCT 56 1200        RC
19 OCT 56 1200       RC
21 OCT 56 1200       RC
23 OCT 56 1200        C
25 OCT 56 1200      RC
27 OCT 56 1200       C
29 OCT 56 1200     RC
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 2 NOV 56 1200       C
 4 NOV 56 1200       C
 6 NOV 56 1200       C
 8 NOV 56 1200      RC
10 NOV 56 1200      RC
12 NOV 56 1200      C
14 NOV 56 1200      C
16 NOV 56 1200     RC
18 NOV 56 1200     C
20 NOV 56 1200     C
22 NOV 56 1200    RC
24 NOV 56 1200    RC
26 NOV 56 1200    RC
28 NOV 56 1200    C
30 NOV 56 1200    C
 2 DEC 56 1200    C
 4 DEC 56 1200   RC
 6 DEC 56 1200   RC
```

```
 8 DEC 56 1200    C
10 DEC 56 1200   RC
12 DEC 56 1200   RC
14 DEC 56 1200   C
16 DEC 56 1200   C
18 DEC 56 1200   C
20 DEC 56 1200   C
22 DEC 56 1200   C
24 DEC 56 1200   C
26 DEC 56 1200   C
28 DEC 56 1200   C
30 DEC 56 1200   C
 1 JAN 57 1200   C
 3 JAN 57 1200   C
 5 JAN 57 1200   C
 7 JAN 57 1200  RC
 9 JAN 57 1200  RC
11 JAN 57 1200  RC
13 JAN 57 1200  RC
15 JAN 57 1200  RC
17 JAN 57 1200  C
19 JAN 57 1200  C
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23 JAN 57 1200  C
25 JAN 57 1200  C
27 JAN 57 1200  C
29 JAN 57 1200  C
31 JAN 57 1200  C
 2 FEB 57 1200  C
 4 FEB 57 1200  C
 6 FEB 57 1200  C
 8 FEB 57 1200  C
10 FEB 57 1200  C
12 FEB 57 1200  C
14 FEB 57 1200  C
16 FEB 57 1200  C
18 FEB 57 1200  C
20 FEB 57 1200  C
22 FEB 57 1200  C
24 FEB 57 1200  C
26 FEB 57 1200  C
28 FEB 57 1200  C
 2 MAR 57 1200 RC
 4 MAR 57 1200 RC
 6 MAR 57 1200  C
 8 MAR 57 1200  C
10 MAR 57 1200  C
12 MAR 57 1200  C
14 MAR 57 1200  C
16 MAR 57 1200  C
18 MAR 57 1200  C
20 MAR 57 1200  C
22 MAR 57 1200  C
24 MAR 57 1200  C
26 MAR 57 1200  C
28 MAR 57 1200  C
30 MAR 57 1200  C
 1 APR 57 1200  C
 3 APR 57 1200  C
 5 APR 57 1200   C
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 7 APR 57 1200    CR
 9 APR 57 1200     CR
11 APR 57 1200      CR
13 APR 57 1200      C
15 APR 57 1200      C
17 APR 57 1200      CR
19 APR 57 1200       C
21 APR 57 1200        RC
23 APR 57 1300           C R
25 APR 57 1200                RC
27 APR 57 1200                   C   R
 9 APR 57 1200                    C  R
 1 MAY 57 1200                   C
 3 MAY 57 1200                C
 5 MAY 57 1200               C
 7 MAY 57 1200             C
 9 MAY 57 1200             C
11 MAY 57 1200            C
13 MAY 57 1200            C
15 MAY 57 1200           C
17 MAY 57 1200           C
19 MAY 57 1200           C
21 MAY 57 1200          C
23 MAY 57 1200         RC
25 MAY 57 1200         C
27 MAY 57 1200         C
29 MAY 57 1200        RC
31 MAY 57 1200        C
 2 JUN 57 1200        C
 4 JUN 57 1200       RC
 6 JUN 57 1200       C
 8 JUN 57 1200       C
10 JUN 57 1200       C
12 JUN 57 1200       C
14 JUN 57 1200      RC
16 JUN 57 1200      C
18 JUN 57 1200      C
20 JUN 57 1200      C
22 JUN 57 1200      C
24 JUN 57 1200     RC
26 JUN 57 1200     C
28 JUN 57 1200     C
30 JUN 57 1200     C
 2 JUL 57 1200     C
 4 JUL 57 1200     C
 6 JUL 57 1200     C
 8 JUL 57 1200     CR
10 JUL 57 1200      C
12 JUL 57 1200      C
14 JUL 57 1200     RC
16 JUL 57 1200     RC
18 JUL 57 1200     CR
20 JUL 57 1200     C
22 JUL 57 1200     RC
24 JUL 57 1200      C
26 JUL 57 1200      C
28 JUL 57 1200      C
30 JUL 57 1200      C
 1 AUG 57 1200      C
 3 AUG 57 1200     RC

 5 AUG 57 1200      C
 7 AUG 57 1200      C
 9 AUG 57 1200      C
11 AUG 57 1200      C
13 AUG 57 1200      C
15 AUG 57 1200      C
17 AUG 57 1200      C
19 AUG 57 1200      C
21 AUG 57 1200      C
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27 AUG 57 1200      C
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31 AUG 57 1200      C
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 4 SEP 57 1200      C
 6 SEP 57 1200      C
 8 SEP 57 1200      C
10 SEP 57 1200      C
12 SEP 57 1200      C
14 SEP 57 1200      C
16 SEP 57 1200      C
18 SEP 57 1200      C
20 SEP 57 1200      C
22 SEP 57 1200      C
24 SEP 57 1200      C
26 SEP 57 1200     C
28 SEP 57 1200     C
30 SEP 57 1200     C
 2 OCT 57 1200     C
 4 OCT 57 1200     C
 6 OCT 57 1200     CR
 8 OCT 57 1200      C
10 OCT 57 1200      C
12 OCT 57 1200      C
14 OCT 57 1200      C
16 OCT 57 1200     CR
18 OCT 57 1200      C
20 OCT 57 1200      CR
22 OCT 57 1200       C
24 OCT 57 1200       CR
26 OCT 57 1200        C
28 OCT 57 1200        C
30 OCT 57 1200        CR
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21 NOV 57 1200    RC
23 NOV 57 1200    C
25 NOV 57 1200    C
27 NOV 57 1200    C
29 NOV 57 1200    C
 1 DEC 57 1200    C
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```
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 7 DEC 87 1200    E
 9 DEC 87 1200    E
11 DEC 87 1200    E
13 DEC 87 1200    E
15 DEC 87 1200    E
17 DEC 87 1200    E
19 DEC 87 1200    E
21 DEC 87 1200   RE
23 DEC 87 1200   RE
25 DEC 87 1200   RE
27 DEC 87 1200   RE
29 DEC 87 1200   RE
31 DEC 87 1200   RE
 2 JAN 88 1200   RE
 4 JAN 88 1200   RE
 6 JAN 88 1200   RE
 8 JAN 88 1200   RE
10 JAN 88 1200   RE
12 JAN 88 1200   RE
14 JAN 88 1200   RE
16 JAN 88 1200   RE
18 JAN 88 1200   RE
20 JAN 88 1200   RE
22 JAN 88 1200   RE
24 JAN 88 1200   RE
26 JAN 88 1200   RE
28 JAN 88 1200   RE
30 JAN 88 1200   RE
 1 FEB 88 1200   RE
 3 FEB 88 1200   RE
 5 FEB 88 1200   RE
 7 FEB 88 1200   RE
 9 FEB 88 1200   RE
11 FEB 88 1200   RE
13 FEB 88 1200   RE
15 FEB 88 1200   RE
17 FEB 88 1200   E
19 FEB 88 1200   E
21 FEB 88 1200   E
23 FEB 88 1200   E
25 FEB 88 1200   E
27 FEB 88 1200   E
 1 MAR 88 1200   E
 3 MAR 88 1200   E
 5 MAR 88 1200   E
 7 MAR 88 1200   E
 9 MAR 88 1200   E
11 MAR 88 1200   E
13 MAR 88 1200   E
15 MAR 88 1200   E
17 MAR 88 1200   E
19 MAR 88 1200   E
21 MAR 88 1200   E
23 MAR 88 1200   E
25 MAR 88 1200   E
27 MAR 88 1200   E
29 MAR 88 1200   E
31 MAR 88 1200   RE
```

```
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 4 APR 88 1200     CR
 6 APR 88 1200        CR
 8 APR 88 1200            C   R
10 APR 88 1200                C  R
12 APR 88 1200                   CR
14 APR 88 1200                    C
16 APR 88 1200                     C
18 APR 88 1200                      CR
20 APR 88 1200                      CR
22 APR 88 1200                      C
24 APR 88 1200                      C
26 APR 88 1200                      C
28 APR 88 1200                     C
30 APR 88 1200                  C
 2 MAY 88 1200                 C
 4 MAY 88 1200               RC
 6 MAY 88 1200             RC
 8 MAY 88 1200            RC
10 MAY 88 1200           RC
12 MAY 88 1200          RC
14 MAY 88 1200        R C
16 MAY 88 1200       RC
18 MAY 88 1200      RC
20 MAY 88 1200     RC
22 MAY 88 1200     RC
24 MAY 88 1200    RC
26 MAY 88 1200    C
28 MAY 88 1200   RC
30 MAY 88 1200   RC
 1 JUN 88 1200   RC
 3 JUN 88 1200   RC
 5 JUN 88 1200   C
 7 JUN 88 1200  RC
 9 JUN 88 1200  C
11 JUN 88 1200 RC
13 JUN 88 1200 C
15 JUN 88 1200 RC
17 JUN 88 1200 RC
19 JUN 88 1200 C
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 1 JUL 88 1200 C
 3 JUL 88 1200 C
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 7 JUL 88 1200RC
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11 JUL 88 1200 C
13 JUL 88 1200 C
15 JUL 88 1200 C
17 JUL 88 1200 C
19 JUL 88 1200RC
21 JUL 88 1200RC
23 JUL 88 1200RC
25 JUL 88 1200 C
27 JUL 88 1200 C
29 JUL 88 1200 C
```

31	JUL	58	1200	C
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4	AUG	58	1200	C
6	AUG	58	1200	C
8	AUG	58	1200	C
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12	AUG	58	1200	C
14	AUG	58	1200	C
16	AUG	58	1200	C
18	AUG	58	1200	C
20	AUG	58	1200	C
22	AUG	58	1200	C
24	AUG	58	1200	C
26	AUG	58	1200	C
28	AUG	58	1200	C
30	AUG	58	1200	C
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9	SEP	58	1200	C
11	SEP	58	1200	C
13	SEP	58	1200	C
15	SEP	58	1200	C
17	SEP	58	1200	CR
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21	SEP	58	1200	CR
23	SEP	58	1200	C
25	SEP	58	1200	C
27	SEP	58	1200	C
29	SEP	58	1200	C
1	OCT	58	1200	C
3	OCT	58	1200	C
5	OCT	58	1200	C
7	OCT	58	1200	C
9	OCT	58	1200	C
11	OCT	58	1200	CR
13	OCT	58	1200	CR
15	OCT	58	1200	CR
17	OCT	58	1200	C
19	OCT	58	1200	C
21	OCT	58	1200	CR
23	OCT	58	1200	C
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4	NOV	58	1200	C
6	NOV	58	1200	C
8	NOV	58	1200	C
10	NOV	58	1200	C
12	NOV	58	1200	C
14	NOV	58	1200	C
16	NOV	58	1200	NC
18	NOV	58	1200	C
20	NOV	58	1200	C
22	NOV	58	1200	C
24	NOV	58	1200	C
26	NOV	58	1200	C
28	NOV	58	1200	C
30	NOV	58	1200	C
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4	DEC	58	1200	C
6	DEC	58	1200	CR
8	DEC	58	1200	C
10	DEC	58	1200	C
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16	DEC	58	1200	C
18	DEC	58	1200	C
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26	DEC	58	1200	C
28	DEC	58	1200	C
30	DEC	58	1200	C
1	JAN	59	1200	C
3	JAN	59	1200	C
5	JAN	59	1200	C
7	JAN	59	1200	C
9	JAN	59	1200	C
11	JAN	59	1200	C
13	JAN	59	1200	C
15	JAN	59	1200	C
17	JAN	59	1200	C
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10	FEB	59	1200	C
12	FEB	59	1200	C
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16	FEB	59	1200	C
18	FEB	59	1200	C
20	FEB	59	1200	C
22	FEB	59	1200	C
24	FEB	59	1200	C
26	FEB	59	1200	C
28	FEB	59	1200	C
2	MAR	59	1200	C
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6	MAR	59	1200	C
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18	MAR	59	1200	C
20	MAR	59	1200	C
22	MAR	59	1200	C
24	MAR	59	1200	CR
26	MAR	59	1200	CR

```
28 MAR 89 1200  CR
30 MAR 89 1200   C
 1 APR 89 1200   C
 3 APR 89 1200   C
 5 APR 89 1200   C
 7 APR 89 1200   C
 9 APR 89 1200    C
11 APR 89 1200    C R
13 APR 89 1200      CR
15 APR 89 1200       CR
17 APR 89 1200       CR
19 APR 89 1200        C
21 APR 89 1200        CR
23 APR 89 1200        C
25 APR 89 1200       C
27 APR 89 1200      C
29 APR 89 1200      C
 1 MAY 89 1200      C
 3 MAY 89 1200     CR
 5 MAY 89 1200     C
 7 MAY 89 1200     C
 9 MAY 89 1200     C
11 MAY 89 1200     CR
13 MAY 89 1200     CR
15 MAY 89 1200      C
17 MAY 89 1200      C
19 MAY 89 1200      C
21 MAY 89 1200    C
23 MAY 89 1200    C
25 MAY 89 1200    C
27 MAY 89 1200    C
29 MAY 89 1200   RC
31 MAY 89 1200   C
 2 JUN 89 1200   C
 4 JUN 89 1200   C
 6 JUN 89 1200   C
 8 JUN 89 1200   C
10 JUN 89 1200   C
12 JUN 89 1200   C
14 JUN 89 1200   C
16 JUN 89 1200   CR
18 JUN 89 1200    C
20 JUN 89 1200     CR
22 JUN 89 1200      CR
24 JUN 89 1200       CR
26 JUN 89 1200       CR
28 JUN 89 1200       CR
30 JUN 89 1200       C
 2 JUL 89 1200       C
 4 JUL 89 1200      RC
 6 JUL 89 1200        CR
 8 JUL 89 1200         CR
10 JUL 89 1200          CR
12 JUL 89 1200          CR
14 JUL 89 1200          CR
16 JUL 89 1200         C
18 JUL 89 1200        C
20 JUL 89 1200       C
22 JUL 89 1200      C
24 JUL 89 1200     RC
```

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26 JUL 89 1200      C
28 JUL 89 1200     C
30 JUL 89 1200     C
 1 AUG 89 1200    RC
 3 AUG 89 1200    C
 5 AUG 89 1200    C
 7 AUG 89 1200    C
 9 AUG 89 1200    C
11 AUG 89 1200    C
13 AUG 89 1200    C
15 AUG 89 1200    C
17 AUG 89 1200    C
19 AUG 89 1200    C
21 AUG 89 1200    C
23 AUG 89 1200    CR
25 AUG 89 1200     C
27 AUG 89 1200      C
29 AUG 89 1200       CR
31 AUG 89 1200         C R
 2 SEP 89 1200           C R
 4 SEP 89 1200             CR
 6 SEP 89 1200              CR
 8 SEP 89 1200              CR
10 SEP 89 1200              C
12 SEP 89 1200            CR
14 SEP 89 1200           C
16 SEP 89 1200          C
18 SEP 89 1200         C
20 SEP 89 1200        C
22 SEP 89 1200        C
24 SEP 89 1200       C
26 SEP 89 1200       C
28 SEP 89 1200       CR
30 SEP 89 1200        C
 2 OCT 89 1200         C
 4 OCT 89 1200          C
 6 OCT 89 1200          CR
 8 OCT 89 1200          C
10 OCT 89 1200          C
12 OCT 89 1200         CR
14 OCT 89 1200         C
16 OCT 89 1200         C
18 OCT 89 1200         C
20 OCT 89 1200         C
22 OCT 89 1200        C
24 OCT 89 1200        C
26 OCT 89 1200        C
28 OCT 89 1200        C
30 OCT 89 1200        C
 1 NOV 89 1200        C
 3 NOV 89 1200        C
 5 NOV 89 1200       CR
 7 NOV 89 1200       RC
 9 NOV 89 1200        C
11 NOV 89 1200        C
13 NOV 89 1200      C
15 NOV 89 1200     RC
17 NOV 89 1200     C
19 NOV 89 1200     C
21 NOV 89 1200     C
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23 NOV 59 1200      RC                                                  *
25 NOV 59 1200       C                                                  *
27 NOV 59 1200       C                                                  *
29 NOV 59 1200      RC                                                  *
 1 DEC 59 1200       C                                                  *
 3 DEC 59 1200       C                                                  *
 5 DEC 59 1200      RC                                                  *
 7 DEC 59 1200      RC                                                  *
 9 DEC 59 1200       C                                                  *
11 DEC 59 1200       C                                                  *
13 DEC 59 1200       C                                                  *
 5 DEC 59 1200       C                                                  *
17 DEC 59 1200      RC                                                  *
19 DEC 59 1200      RC                                                  *
21 DEC 59 1200      RC                                                  *
23 DEC 59 1200      C                                                   *
25 DEC 59 1200      C                                                   *
27 DEC 59 1200      C                                                   *
29 DEC 59 1200      C                                                   *
31 DEC 59 1200      C                                                   *
```

```
                                  PLOT     STATION NAME                                STATION
                                CHARACTER                                             NUMBER CONTROL

                                    C-CALC  BEAVER RIVER FLOW AT COLD LAKE                 726.0   0
                                    R-BEAVER R. AT COLD LAKE 05AD005                        52.6   0
FLOW CFS          0.      1500.     3000.     4500.     6000.     7500.     9000.    10500.    12000.    13500     15000.
                                    *-DUMMY RES  (DIFF) AT BEAVER RIVER AT COLD LA         726.2   E
ELEV FT.         -5.       -4.       -3.       -2.       -1.       -0.        1.        2.        3.        4.        5.
 1 JAN 60 1200   .C        .         .         .         .         *         .         .         .         .         .
 3 JAN 60 1200   .C        .         .         .         .         *         .         .         .         .         .
 5 JAN 60 1200   .C        .         .         .         .         *         .         .         .         .         .
 7 JAN 60 1200   .C        .         .         .         .         *         .         .         .         .         .
 9 JAN 60 1200   .C        .         .         .         .         *         .         .         .         .         .
11 JAN 60 1200   .C        .         .         .         .         *         .         .         .         .         .
13 JAN 60 1200   .C        .         .         .         .         *         .         .         .         .         .
15 JAN 60 1200   .C        .         .         .         .         *         .         .         .         .         .
17 JAN 60 1200   .C        .         .         .         .         *         .         .         .         .         .
19 JAN 60 1200   .C        .         .         .         .         *         .         .         .         .         .
21 JAN 60 1200   .C        .         .         .         .         *         .         .         .         .         .
23 JAN 60 1200   .C        .         .         .         .         *         .         .         .         .         .
25 JAN 60 1200   .C        .         .         .         .         *         .         .         .         .         .
27 JAN 60 1200   .C        .         .         .         .         *         .         .         .         .         .
29 JAN 60 1200   RC        .         .         .         .         *         .         .         .         .         .
31 JAN 60 1200   RC        .         .         .         .         *         .         .         .         .         .
 2 FEB 60 1200   RC        .         .         .         .         *         .         .         .         .         .
 4 FEB 60 1200   RC        .         .         .         .         *         .         .         .         .         .
 6 FEB 60 1200   RC        .         .         .         .         *         .         .         .         .         .
 8 FEB 60 1200   RC        .         .         .         .         *         .         .         .         .         .
10 FEB 60 1200   C         .         .         .         .         *         .         .         .         .         .
12 FEB 60 1200   C         .         .         .         .         *         .         .         .         .         .
14 FEB 60 1200   C         .         .         .         .         *         .         .         .         .         .
16 FEB 60 1200   C         .         .         .         .         *         .         .         .         .         .
18 FEB 60 1200   C         .         .         .         .         *         .         .         .         .         .
20 FEB 60 1200   C         .         .         .         .         *         .         .         .         .         .
22 FEB 60 1200   C         .         .         .         .         *         .         .         .         .         .
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 5 MAR 60 1200   C         .         .         .         .         *         .         .         .         .         .
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17 MAR 60 1200   C         .         .         .         .         *         .         .         .         .         .
19 MAR 60 1200   C         .         .         .         .         *         .         .         .         .         .
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23 MAR 60 1200   C         .         .         .         .         *         .         .         .         .         .
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27 MAR 60 1200   C R       .         .         .         .         *         .         .         .         .         .
29 MAR 60 1200   .C        .         .         .         .         *         .         .         .         .         .
31 MAR 60 1200   .C        .         .         .         .         *         .         .         .         .         .
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 4 APR 60 1200   .RC       .         .         .         .         *         .         .         .         .         .
 6 APR 60 1200   . CR      .         .         .         .         *         .         .         .         .         .
 8 APR 60 1200   .  C R    .         .         .         .         *         .         .         .         .         .
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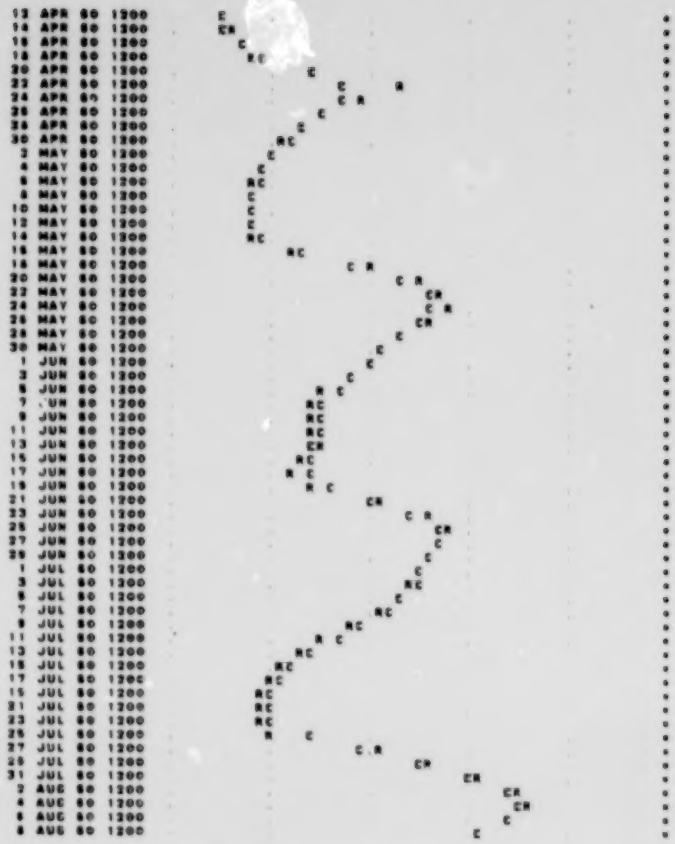
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16 AUG 80 1200
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2 DEC 80 1200
4 DEC 80 1200
6 DEC 80 1200

```
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10 DEC 80 1200      RC
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14 DEC 80 1200      C
16 DEC 80 1200      C
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13 JAN 81 1200      C
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19 JAN 81 1200     RC
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23 JAN 81 1200     RC
25 JAN 81 1200     RC
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 6 FEB 81 1200      C
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10 FEB 81 1200      C
12 FEB 81 1200      C
14 FEB 81 1200      C
16 FEB 81 1200      C
18 FEB 81 1200      C
20 FEB 81 1200      C
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24 FEB 81 1200      C
26 FEB 81 1200      C
28 FEB 81 1200      C
 2 MAR 81 1200      C
 4 MAR 81 1200      C
 6 MAR 81 1200      C
 8 MAR 81 1200      C
10 MAR 81 1200      C
12 MAR 81 1200      C
14 MAR 81 1200      C
16 MAR 81 1200      C
18 MAR 81 1200      C
20 MAR 81 1200      C
22 MAR 81 1200      C
24 MAR 81 1200      C
26 MAR 81 1200      C
28 MAR 81 1200     RC
30 MAR 81 1200     RC
 1 APR 81 1200      C
 3 APR 81 1200      CR
 5 APR 81 1200      CR

 7 APR 81 1200      CR
 9 APR 81 1200      RC
11 APR 81 1200      CR
13 APR 81 1200      C
15 APR 81 1200    R C
17 APR 81 1200     RC
19 APR 81 1200       C
21 APR 81 1200           RC
23 APR 81 1200                 C     R
25 APR 81 1200                       C
27 APR 81 1200                         C R
29 APR 81 1200                          CR
 1 MAY 81 1200                          C
 3 MAY 81 1200                        C
 5 MAY 81 1200                        CR
 7 MAY 81 1200                         C
 9 MAY 81 1200                         C
11 MAY 81 1200                         C
13 MAY 81 1200                       C
15 MAY 81 1200                      C
17 MAY 81 1200                     RC
19 MAY 81 1200                    RC
21 MAY 81 1200                   RC
23 MAY 81 1200                  RC
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27 MAY 81 1200                C
29 MAY 81 1200              RC
31 MAY 81 1200              C
 2 JUN 81 1200            RC
 4 JUN 81 1200            C
 6 JUN 81 1200          RC
 8 JUN 81 1200         RC
10 JUN 81 1200        RC
12 JUN 81 1200      R C
14 JUN 81 1200      RC
16 JUN 81 1200       C
18 JUN 81 1200       C
20 JUN 81 1200      RC
22 JUN 81 1200      C
24 JUN 81 1200      C
26 JUN 81 1200     RC
28 JUN 81 1200     RC
30 JUN 81 1200     RC
 2 JUL 81 1200      C
 4 JUL 81 1200       C
 6 JUL 81 1200       C
 8 JUL 81 1200      RC
10 JUL 81 1200      C
12 JUL 81 1200     RC
14 JUL 81 1200     C
16 JUL 81 1200    RC
18 JUL 81 1200    C
20 JUL 81 1200    C
22 JUL 81 1200    C
24 JUL 81 1200    C
26 JUL 81 1200     C
28 JUL 81 1200       C
30 JUL 81 1200         CR
 1 AUG 81 1200           C R
 3 AUG 81 1200            C
```

```
 5 AUG 61 1200                 C
 7 AUG 61 1200                C
 9 AUG 61 1200              C
11 AUG 61 1200            C
13 AUG 61 1200          C
15 AUG 61 1200        C
17 AUG 61 1200      C
19 AUG 61 1200     RC
21 AUG 61 1200      C
23 AUG 61 1200    RC
25 AUG 61 1200     C
27 AUG 61 1200   RC
29 AUG 61 1200    C
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 4 SEP 61 1200  RC
 6 SEP 61 1200  C
 8 SEP 61 1200  C
10 SEP 61 1200  C
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14 SEP 61 1200  C
16 SEP 61 1200  C
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20 SEP 61 1200 RC
22 SEP 61 1200 C
24 SEP 61 1200 C
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30 SEP 61 1200 C
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 4 OCT 61 1200 C
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30 OCT 61 1200 C
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15 NOV 61 1200 C
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19 NOV 61 1200 C
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23 NOV 61 1200 C
25 NOV 61 1200 C
27 NOV 61 1200 C
29 NOV 61 1200 C
 1 DEC 61 1200 C
```

```
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 5 DEC 61 1200 C
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19 DEC 61 1200 C
21 DEC 61 1200 C
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 4 JAN 62 1200 C
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 8 JAN 62 1200 C
10 JAN 62 1200 C
12 JAN 62 1200 C
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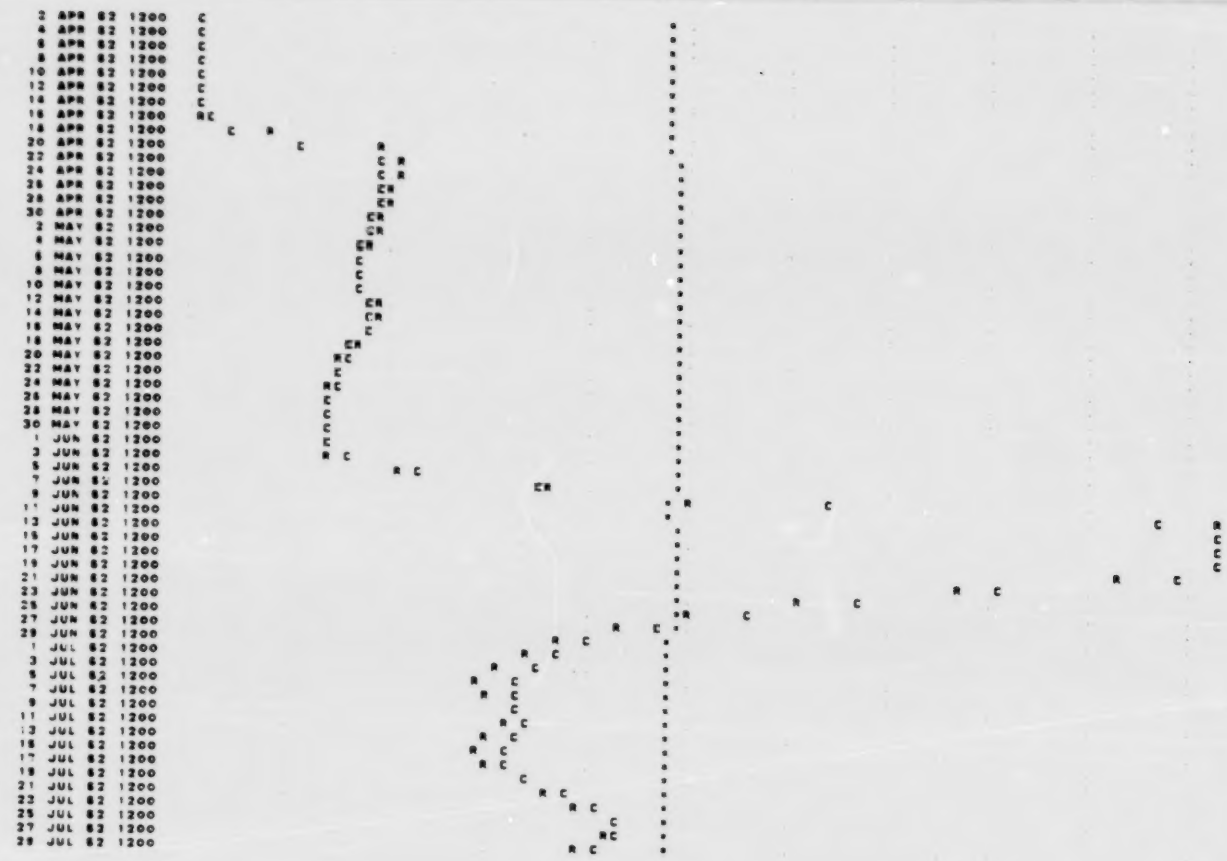
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6 MAY 82 1200
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9 JUN 82 1200
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15 JUN 82 1200
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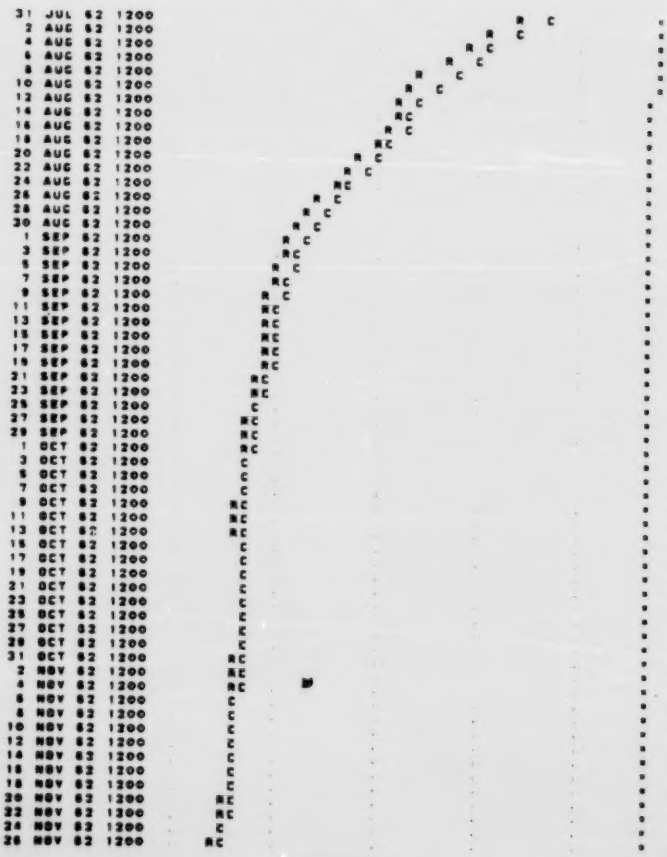
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18 AUG 82 1200
20 AUG 82 1200
22 AUG 82 1200
24 AUG 82 1200
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28 AUG 82 1200
30 AUG 82 1200
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18 NOV 82 1200
20 NOV 82 1200
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24 NOV 82 1200
26 NOV 82 1200

28	NOV	62	1200	C
30	NOV	62	1200	C
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4	DEC	62	1200	RC
6	DEC	62	1200	C
8	DEC	62	1200	C
10	DEC	62	1200	C
12	DEC	62	1200	C
14	DEC	62	1200	C
16	DEC	62	1200	RC
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10	FEB	63	1200	RC
12	FEB	63	1200	RC
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18	FEB	63	1200	RC
20	FEB	63	1200	RC
22	FEB	63	1200	RC
24	FEB	63	1200	RC
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10	MAR	63	1200	RC
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7	APR	63	1200	C
9	APR	63	1200	C
11	APR	63	1200	C
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19	APR	63	1200	C R
21	APR	63	1200	C R
23	APR	63	1200	R C
25	APR	63	1200	CR
27	APR	63	1200	
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5	MAY	63	1200	RC
7	MAY	63	1200	RC
9	MAY	63	1200	RC
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16	JUN	63	1200	RC
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19	DEC	63	1200	C
21	DEC	63	1200	C
23	DEC	63	1200	C
25	DEC	63	1200	C
27	DEC	63	1200	C
29	DEC	63	1200	C
31	DEC	63	1200	C

```
                                    PLOT     STATION NAME                                    STATION
                                  CHARACTER                                                 NUMBER CONTROL

                                      C-CALC. BEAVER RIVER FLOW AT COLD LAKE                  726.0   0
                                      R-BEAVER R. AT COLD LAKE 08AD005                         52.8   0
FLOW CFS          0.      1500      3000.      4500.      6000.      7500.      9000      10500.     12000.     13500      15000
                                      *-DUMMY RES. (DIFF) AT BEAVER RIVER AT COLD LA          726.2   E
ELEV FT.         -5.       -4.       -3.       -2.       -1.       -0.        1.        2.        3.        4.        5.
 1 JAN 64 1200   C
 3 JAN 64 1200   C
 5 JAN 64 1200   C
 7 JAN 64 1200   C
 9 JAN 64 1200   C
11 JAN 64 1200   C
13 JAN 64 1200   C
15 JAN 64 1200   C
17 JAN 64 1200   C
19 JAN 64 1200   C
21 JAN 64 1200   C
23 JAN 64 1200   C
25 JAN 64 1200   C
27 JAN 64 1200   C
29 JAN 64 1200   C
31 JAN 64 1200   C
 2 FEB 64 1200   C
 4 FEB 64 1200   C
 6 FEB 64 1200   C
 8 FEB 64 1200   C
10 FEB 64 1200   C
12 FEB 64 1200   C
14 FEB 64 1200   C
16 FEB 64 1200   C
18 FEB 64 1200   C
20 FEB 64 1200   C
22 FEB 64 1200   C
24 FEB 64 1200   C
26 FEB 64 1200   C
28 FEB 64 1200   C
 1 MAR 64 1200   C
 3 MAR 64 1200   C
 5 MAR 64 1200   C
 7 MAR 64 1200   C
 9 MAR 64 1200   C
11 MAR 64 1200   C
13 MAR 64 1200   C
15 MAR 64 1200   C
17 MAR 64 1200   C
19 MAR 64 1200   C
21 MAR 64 1200   CR
23 MAR 64 1200   CR
25 MAR 64 1200   CR
27 MAR 64 1200   CR
29 MAR 64 1200   CR
31 MAR 64 1200   C
 2 APR 64 1200   C
 4 APR 64 1200   CR
 6 APR 64 1200   CR
 8 APR 64 1200   .C
10 APR 64 1200   .CR
```

```
12 APR 84 1200  .CR
14 APR 84 1200  . C R
16 APR 84 1200  .   C   R
18 APR 84 1200  .       C
20 APR 84 1200  .       C
22 APR 84 1200  .     C
24 APR 84 1200  .     C
26 APR 84 1200  .     C
28 APR 84 1200  .     C
30 APR 84 1200  .     C
 2 MAY 84 1200  .     C
 4 MAY 84 1200  .       CR
 6 MAY 84 1200  .         CR
 8 MAY 84 1200  .         CR
10 MAY 84 1200  .           CR
12 MAY 84 1200  .             C
14 MAY 84 1200  .             CR
16 MAY 84 1200  .             CR
18 MAY 84 1200  .           CR
20 MAY 84 1200  .           C
22 MAY 84 1200  .         C
24 MAY 84 1200  .         C
26 MAY 84 1200  .       C
28 MAY 84 1200  .       C
30 MAY 84 1200  .       C
 1 JUN 84 1200  .     CR
 3 JUN 84 1200  .     C
 5 JUN 84 1200  .     C
 7 JUN 84 1200  .   C
 9 JUN 84 1200  .   C
11 JUN 84 1200  .  C
13 JUN 84 1200  .  C
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 7 JUL 84 1200 C
 9 JUL 84 1200 C
11 JUL 84 1200 C
13 JUL 84 1200 C
15 JUL 84 1200 CR
17 JUL 84 1200 C
19 JUL 84 1200 C
21 JUL 84 1200 C
23 JUL 84 1200 C
25 JUL 84 1200 CR
27 JUL 84 1200 CR
29 JUL 84 1200  C
31 JUL 84 1200  C
 2 AUG 84 1200  C
 4 AUG 84 1200  CR
 6 AUG 84 1200  CR
 8 AUG 84 1200   C
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10 AUG 84 1200   C
12 AUG 84 1200   C
14 AUG 84 1200   C
16 AUG 84 1200   C
18 AUG 84 1200  CR
20 AUG 84 1200  C
22 AUG 84 1200  C
24 AUG 84 1200  C
26 AUG 84 1200  C
28 AUG 84 1200  C
30 AUG 84 1200  C
 1 SEP 84 1200  C
 3 SEP 84 1200  C
 5 SEP 84 1200  CR
 7 SEP 84 1200   CR
 9 SEP 84 1200   CR
11 SEP 84 1200     C
13 SEP 84 1200     CR
15 SEP 84 1200       C
17 SEP 84 1200       CR
19 SEP 84 1200         C
21 SEP 84 1200         CR
23 SEP 84 1200           C
25 SEP 84 1200           C
27 SEP 84 1200           C
29 SEP 84 1200           C
 1 OCT 84 1200         CR
 3 OCT 84 1200         CR
 5 OCT 84 1200         C
 7 OCT 84 1200         C
 9 OCT 84 1200         C
11 OCT 84 1200       CR
13 OCT 84 1200       C
15 OCT 84 1200       C
17 OCT 84 1200       C
19 OCT 84 1200     C
21 OCT 84 1200     C
23 OCT 84 1200     C
25 OCT 84 1200    RC
27 OCT 84 1200    C
29 OCT 84 1200    C
31 OCT 84 1200    C
 2 NOV 84 1200    C
 4 NOV 84 1200    C
 6 NOV 84 1200    C
 8 NOV 84 1200   RC
10 NOV 84 1200   C
12 NOV 84 1200   C
14 NOV 84 1200   C
16 NOV 84 1200   C
18 NOV 84 1200   C
20 NOV 84 1200   C
22 NOV 84 1200   C
24 NOV 84 1200   C
26 NOV 84 1200   C
28 NOV 84 1200   C
30 NOV 84 1200  RC
 2 DEC 84 1200  RC
 4 DEC 84 1200  C
 6 DEC 84 1200  C
```

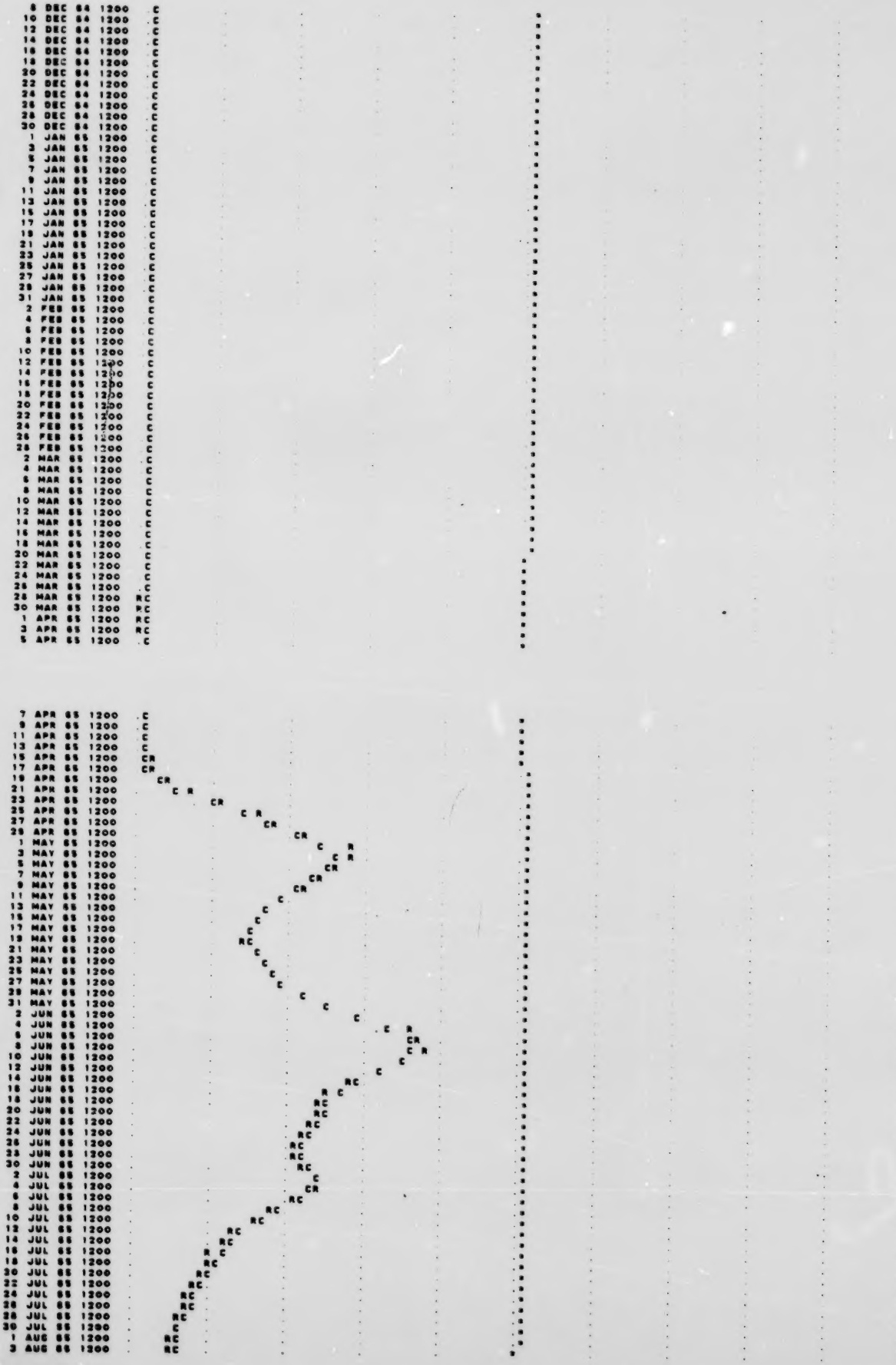
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10 DEC 84 1200
12 DEC 84 1200
14 DEC 84 1200
16 DEC 84 1200
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22 DEC 84 1200
24 DEC 84 1200
26 DEC 84 1200
28 DEC 84 1200
30 DEC 84 1200
1 JAN 85 1200
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1 AUG 85 1200
3 AUG 85 1200

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 9 AUG 65 1200        C
11 AUG 65 1200        C
13 AUG 65 1200       RC
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17 AUG 65 1200       RC
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29 AUG 65 1200        C
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 2 SEP 65 1200          C
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12 SEP 65 1200               C
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16 SEP 65 1200              C
18 SEP 65 1200             C
20 SEP 65 1200             C
22 SEP 65 1200            RC
24 SEP 65 1200            C
26 SEP 65 1200            C
28 SEP 65 1200            C
30 SEP 65 1200           RC
 2 OCT 65 1200           RC
 4 OCT 65 1200           C
 6 OCT 65 1200           C
 8 OCT 65 1200           C
10 OCT 65 1200           C
12 OCT 65 1200           C
14 OCT 65 1200          RC
16 OCT 65 1200          RC
18 OCT 65 1200          C
20 OCT 65 1200          C
22 OCT 65 1200          C
24 OCT 65 1200          C
26 OCT 65 1200          C
28 OCT 65 1200          C
30 OCT 65 1200          C
 1 NOV 65 1200          C
 3 NOV 65 1200          C
 5 NOV 65 1200         RC
 7 NOV 65 1200         C
 9 NOV 65 1200         C
11 NOV 65 1200         C
13 NOV 65 1200         C
15 NOV 65 1200        RC
17 NOV 65 1200        RC
19 NOV 65 1200        RC
21 NOV 65 1200        RC
23 NOV 65 1200        RC
25 NOV 65 1200        RC
27 NOV 65 1200        RC
29 NOV 65 1200        C
 1 DEC 65 1200        C
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 3 DEC 65 1200        C
 5 DEC 65 1200        C
 7 DEC 65 1200        C
 9 DEC 65 1200        C
11 DEC 65 1200        C
13 DEC 65 1200        C
15 DEC 65 1200        C
17 DEC 65 1200        C
19 DEC 65 1200        C
21 DEC 65 1200        C
23 DEC 65 1200        C
25 DEC 65 1200       RC
27 DEC 65 1200       RC
29 DEC 65 1200       RC
31 DEC 65 1200       C
 3 JAN 66 1200       C
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 1 FEB 66 1200       C
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25 FEB 66 1200       C
27 FEB 66 1200       C
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21 MAR 66 1200       C
23 MAR 66 1200       C
25 MAR 66 1200       C
27 MAR 66 1200       C
29 MAR 66 1200      RC
31 MAR 66 1200       CR
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2 APR 66 1200
4 APR 66 1200
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1 JUL 66 1200
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31 JUL 66 1200
2 AUG 66 1200
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20 NOV 66 1200
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26 NOV 66 1200

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 7 JAN 87 1200  .C
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23 JAN 87 1200  .C
25 JAN 87 1200  .C
27 JAN 87 1200  .C
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 4 FEB 87 1200  .C
 6 FEB 87 1200  .C
 8 FEB 87 1200  .C
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20 FEB 87 1200  .C
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24 FEB 87 1200  .C
26 FEB 87 1200  .C
28 FEB 87 1200  .C
 2 MAR 87 1200  .C
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 8 MAR 87 1200  .C
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18 MAR 87 1200  .C
20 MAR 87 1200  .C
22 MAR 87 1200  .C
24 MAR 87 1200  .C
26 MAR 87 1200  .C
28 MAR 87 1200  .C
30 MAR 87 1200  .C
 1 APR 87 1200  .C
 3 APR 87 1200  .C
 5 APR 87 1200  .C
 7 APR 87 1200  .C
 9 APR 87 1200  .C
11 APR 87 1200  .C
13 APR 87 1200  .C
15 APR 87 1200  .C
17 APR 87 1200  .C
19 APR 87 1200  .C
21 APR 87 1200  .  C
23 APR 87 1200  .    C
25 APR 87 1200  .      CR
27 APR 87 1200  .            .C
29 APR 87 1200  .                  C   R
 1 MAY 87 1200  .                      C     R
 3 MAY 87 1200  .                        CR
 5 MAY 87 1200  .                        CR
 7 MAY 87 1200  .                        CR
 9 MAY 87 1200  .                       C R
11 MAY 87 1200  .                      CR
13 MAY 87 1200  .                   CR
15 MAY 87 1200  .                RC
17 MAY 87 1200  .              C
19 MAY 87 1200  .            C
21 MAY 87 1200  .          C
23 MAY 87 1200  .        C
25 MAY 87 1200  .      RC
27 MAY 87 1200  .     C
29 MAY 87 1200  .    RC
31 MAY 87 1200  .    C
 2 JUN 87 1200  .   C
 4 JUN 87 1200  .  C
 6 JUN 87 1200  .  C
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10 JUN 87 1200  . C
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18 JUN 87 1200  . C
20 JUN 87 1200  .  C
22 JUN 87 1200  .  C
24 JUN 87 1200  .   C
26 JUN 87 1200  .   C
28 JUN 87 1200  .  RC
30 JUN 87 1200  .  C
 2 JUL 87 1200  .  C
 4 JUL 87 1200  .  C
 6 JUL 87 1200  .  C
 8 JUL 87 1200  .  C
10 JUL 87 1200  . CR
12 JUL 87 1200  . C
14 JUL 87 1200  . C
16 JUL 87 1200  . C
18 JUL 87 1200  . C
20 JUL 87 1200  . C
22 JUL 87 1200  . C
24 JUL 87 1200  . C
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28	JUL	67	1200	C
28	JUL	67	1200	C
30	JUL	67	1200	C
1	AUG	67	1200	C
3	AUG	67	1200	CR
5	AUG	67	1200	CR
7	AUG	67	1200	CR
9	AUG	67	1200	CR
11	AUG	67	1200	C
13	AUG	67	1200	C
15	AUG	67	1200	C
17	AUG	67	1200	C
19	AUG	67	1200	C
21	AUG	67	1200	C
23	AUG	67	1200	C
25	AUG	67	1200	C
27	AUG	67	1200	C
29	AUG	67	1200	CR
31	AUG	67	1200	C
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18	SEP	67	1200	C
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22	SEP	67	1200	C
24	SEP	67	1200	C
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4	OCT	67	1200	C
6	OCT	67	1200	C
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10	OCT	67	1200	C
12	OCT	67	1200	C
14	OCT	67	1200	C
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18	OCT	67	1200	C
20	OCT	67	1200	C
22	OCT	67	1200	C
24	OCT	67	1200	C
26	OCT	67	1200	C
28	OCT	67	1200	C
30	OCT	67	1200	C
1	NOV	67	1200	C
3	NOV	67	1200	C
5	NOV	67	1200	C
7	NOV	67	1200	C
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11	NOV	67	1200	C
13	NOV	67	1200	C
15	NOV	67	1200	C
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21	NOV	67	1200	C
23	NOV	67	1200	C
25	NOV	67	1200	C
27	NOV	67	1200	C
29	NOV	67	1200	C
1	DEC	67	1200	RC
3	DEC	67	1200	RC
5	DEC	67	1200	C
7	DEC	67	1200	C
9	DEC	67	1200	C
11	DEC	67	1200	C
13	DEC	67	1200	C
15	DEC	67	1200	C
17	DEC	67	1200	C
19	DEC	67	1200	C
21	DEC	67	1200	C
23	DEC	67	1200	C
25	DEC	67	1200	C
27	DEC	67	1200	C
29	DEC	67	1200	C
31	DEC	67	1200	C

```
                                    PLOT      STATION NAME                                  STATION
                                  CHARACTER                                                NUMBER CONTROL

                                      C-CALC. BEAVER RIVER FLOW AT COLD LAKE                 726.0    0
                                      R-BEAVER R.  AT COLD LAKE 06AD006                      52.5    0
FLOW CFS          0.      1500.      3000      4500.      6000.      7500      9000      10500.     12000      13500.      15000
                                      *-DUMMY RES.  (DIFF) AT BEAVER RIVER AT COLD LA        726.2    E
ELEV FT.         -5        -4.        -3.        -2.        -1.        -0         1         2         3         4         5
 1 JAN 68 1200   C
 3 JAN 68 1200   C
 5 JAN 68 1200   C
 7 JAN 68 1200   C
 9 JAN 68 1200   C
11 JAN 68 1200   C
13 JAN 68 1200   C
15 JAN 68 1200   C
17 JAN 68 1200   C
19 JAN 68 1200   C
21 JAN 68 1200   C
23 JAN 68 1200   C
25 JAN 68 1200   C
27 JAN 68 1200   C
29 JAN 68 1200   C
31 JAN 68 1200   C
 2 FEB 68 1200   C
 4 FEB 68 1200   C
 6 FEB 68 1200   C
 8 FEB 68 1200   C
10 FEB 68 1200   C
12 FEB 68 1200   C
14 FEB 68 1200   C
16 FEB 68 1200   C
18 FEB 68 1200   C
20 FEB 68 1200   C
22 FEB 68 1200   C
24 FEB 68 1200   C
26 FEB 68 1200   CR
28 FEB 68 1200   CR
 1 MAR 68 1200   CR
 3 MAR 68 1200   CR
 5 MAR 68 1200   CR
 7 MAR 68 1200   CR
 9 MAR 68 1200   CR
11 MAR 68 1200   CR
13 MAR 68 1200   CR
15 MAR 68 1200   .C
17 MAR 68 1200   .C
19 MAR 68 1200   .C
21 MAR 68 1200   .C
23 MAR 68 1200   .C
25 MAR 68 1200   .C
27 MAR 68 1200   .C
29 MAR 68 1200    C
31 MAR 68 1200    C
 2 APR 68 1200    RC
 4 APR 68 1200     C
 6 APR 68 1200     C
 8 APR 68 1200     C
10 APR 68 1200     C
```

```
12 APR 72 1300     CR
14 APR 72 1300      C R
16 APR 72 1200        C R
18 APR 72 1200          C
20 APR 72 1200            CR
22 APR 72 1300              C  R
24 APR 72 1200               C  R
26 APR 72 1200                CR
28 APR 72 1200                  CR
30 APR 72 1200                    C
 2 MAY 72 1200                      RC
 4 MAY 72 1200                       R C
 6 MAY 72 1200                       RC
 8 MAY 72 1200                     R  C
10 MAY 72 1200                    RC
12 MAY 72 1200                   C
14 MAY 72 1200                  RC
16 MAY 72 1200                 C
18 MAY 72 1200               RC
20 MAY 72 1200               C
22 MAY 72 1200              C
24 MAY 72 1200             C
26 MAY 72 1200            C
28 MAY 72 1200           C
30 MAY 72 1200          C
 1 JUN 72 1200         C
 3 JUN 72 1200        C
 5 JUN 72 1200       C
 7 JUN 72 1200      RC
 9 JUN 72 1200     RC
11 JUN 72 1200     C
13 JUN 72 1200     C
15 JUN 72 1200    C
17 JUN 72 1200    C
19 JUN 72 1200    C
21 JUN 72 1200    C
23 JUN 72 1200   RC
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27 JUN 72 1200   C
29 JUN 72 1200   C
 1 JUL 72 1200   C
 3 JUL 72 1200   C
 5 JUL 72 1200   C
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 9 JUL 72 1200  RC
11 JUL 72 1200  C
13 JUL 72 1200  C
15 JUL 72 1200  C
17 JUL 72 1200  C
19 JUL 72 1200  C
21 JUL 72 1200  C
23 JUL 72 1200  C
25 JUL 72 1200  C
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29 JUL 72 1200  C
31 JUL 72 1200  C
 2 AUG 72 1200  C
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16 AUG 72 1200  C
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26 AUG 72 1200 .C
28 AUG 72 1200 .C
30 AUG 72 1200 .C
 1 SEP 72 1200 .C
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 5 SEP 72 1200 .C
 7 SEP 72 1200 .C
 9 SEP 72 1200 .C
11 SEP 72 1200 .C
13 SEP 72 1200 .C
15 SEP 72 1200 .C
17 SEP 72 1200 .C
19 SEP 72 1200 .C
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23 SEP 72 1200 .C
25 SEP 72 1200 .C
27 SEP 72 1200 .C
29 SEP 72 1200 .CR
 1 OCT 72 1200 .CR
 3 OCT 72 1200 .CR
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 7 OCT 72 1200 .C
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11 OCT 72 1200 .C
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15 OCT 72 1200 .C
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19 OCT 72 1200 .C
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29 OCT 72 1200 .C
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18 NOV 72 1200 .C
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22 NOV 72 1200 .C
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 2 DEC 72 1200 .C
 4 DEC 72 1200 .C
 6 DEC 72 1200 .C
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 8 DEC 72 1200  RC
10 DEC 72 1200  RC
12 DEC 72 1200  RC
14 DEC 72 1200  RC
16 DEC 72 1200  RC
18 DEC 72 1200  RC
20 DEC 72 1200  RC
22 DEC 72 1200  RC
24 DEC 72 1200  RC
26 DEC 72 1200   C
28 DEC 72 1200   C
30 DEC 72 1200   C
 1 JAN 73 1200   C
 3 JAN 73 1200   C
 5 JAN 73 1200   C
 7 JAN 73 1200   C
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11 JAN 73 1200   C
13 JAN 73 1200   C
15 JAN 73 1200  RC
17 JAN 73 1200   C
19 JAN 73 1200   C
21 JAN 73 1200   C
23 JAN 73 1200   C
25 JAN 73 1200   C
27 JAN 73 1200   C
29 JAN 73 1200   C
31 JAN 73 1200   C
 2 FEB 73 1200   C
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10 FEB 73 1200   C
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24 FEB 73 1200   C
26 FEB 73 1200  CR
28 FEB 73 1200  CR
 2 MAR 73 1200  CR
 4 MAR 73 1200  C
 6 MAR 73 1200  C
 8 MAR 73 1200  C
10 MAR 73 1200  C
12 MAR 73 1200  C
14 MAR 73 1200  C
16 MAR 73 1200  C
18 MAR 73 1200  C
20 MAR 73 1200  CR
22 MAR 73 1200  CR
24 MAR 73 1200   C
26 MAR 73 1200   C
28 MAR 73 1200   C
30 MAR 73 1200   C
 1 APR 73 1200   C
 3 APR 73 1200  CR
 5 APR 73 1200   C
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 7 APR 73 1200     RC
 9 APR 73 1200      RC
11 APR 73 1200       C
13 APR 73 1200      CR
15 APR 73 1200        C
17 APR 73 1200        C
19 APR 73 1200       C
21 APR 73 1200       C
23 APR 73 1200       C
25 APR 73 1200       C
27 APR 73 1200       C
29 APR 73 1200       C
 1 MAY 73 1200       C
 3 MAY 73 1200       C
 5 MAY 73 1200      RC
 7 MAY 73 1200       C
 9 MAY 73 1200        C
11 MAY 73 1200         C
13 MAY 73 1200         RC
15 MAY 73 1200         RC
17 MAY 73 1200         RC
19 MAY 73 1200         RC
21 MAY 73 1200       RC
23 MAY 73 1200       RC
25 MAY 73 1200       C
27 MAY 73 1200      RC
29 MAY 73 1200      RC
31 MAY 73 1200      C
 2 JUN 73 1200      C
 4 JUN 73 1200      RC
 6 JUN 73 1200        C
 8 JUN 73 1200          C
10 JUN 73 1200          RC
12 JUN 73 1200          RC
14 JUN 73 1200          RC
16 JUN 73 1200           R C
18 JUN 73 1200                  C R
20 JUN 73 1200                        C
22 JUN 73 1200                         C
24 JUN 73 1200                       CR
26 JUN 73 1200                    C
28 JUN 73 1200                 RC
30 JUN 73 1200                 C
 2 JUL 73 1200                 C
 4 JUL 73 1200                C
 6 JUL 73 1200               C
 8 JUL 73 1200             RC
10 JUL 73 1200            C
12 JUL 73 1200          C
14 JUL 73 1200           C
16 JUL 73 1200         RC
18 JUL 73 1200         C
20 JUL 73 1200         C
22 JUL 73 1200         C
24 JUL 73 1200       RC
26 JUL 73 1200       RC
28 JUL 73 1200       C
30 JUL 73 1200       C
 1 AUG 73 1200     RC
 3 AUG 73 1200     RC
```

5	AUG	73	1200	RC
7	AUG	73	1200	C
9	AUG	73	1200	C
11	AUG	73	1200	RC
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15	AUG	73	1200	C
17	AUG	73	1200	C
19	AUG	73	1200	RC
21	AUG	73	1200	RC
23	AUG	73	1200	RC
25	AUG	73	1200	R C
7	AUG	73	1200	C
29	AUG	73	1200	C
31	AUG	73	1200	CR
2	SEP	73	1200	CR
4	SEP	73	1200	CR
6	SEP	73	1200	C
8	SEP	73	1200	C
10	SEP	73	1200	C
12	SEP	73	1200	RC
14	SEP	73	1200	RC
16	SEP	73	1200	C
18	SEP	73	1200	C
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28	SEP	73	1200	C
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4	OCT	73	1200	C
6	OCT	73	1200	RC
8	OCT	73	1200	C
10	OCT	73	1200	C
12	OCT	73	1200	C
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26	OCT	73	1200	C
28	OCT	73	1200	C
30	OCT	73	1200	RC
1	NOV	73	1200	RC
3	NOV	73	1200	RC
5	NOV	73	1200	R C
7	NOV	73	1200	R C
9	NOV	73	1200	R C
11	NOV	73	1200	R C
13	NOV	73	1200	R C
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3	DEC	73	1200	RC
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11	DEC	73	1200	C
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25	DEC	73	1200	C
27	DEC	73	1200	RC
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2	JAN	74	1200	RC
4	JAN	74	1200	RC
6	JAN	74	1200	RC
8	JAN	74	1200	RC
10	JAN	74	1200	C
12	JAN	74	1200	C
14	JAN	74	1200	C
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18	JAN	74	1200	RC
20	JAN	74	1200	RC
22	JAN	74	1200	RC
24	JAN	74	1200	RC
26	JAN	74	1200	RC
28	JAN	74	1200	RC
30	JAN	74	1200	RC
1	FEB	74	1200	RC
3	FEB	74	1200	RC
5	FEB	74	1200	RC
7	FEB	74	1200	RC
9	FEB	74	1200	RC
11	FEB	74	1200	RC
13	FEB	74	1200	RC
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17	FEB	74	1200	RC
19	FEB	74	1200	RC
21	FEB	74	1200	RC
23	FEB	74	1200	RC
25	FEB	74	1200	RC
27	FEB	74	1200	C
1	MAR	74	1200	C
3	MAR	74	1200	C
5	MAR	74	1200	C
7	MAR	74	1200	C
9	MAR	74	1200	C
11	MAR	74	1200	C
13	MAR	74	1200	C
5	MAR	74	1200	C
7	MAR	74	1200	C
19	MAR	74	1200	C
21	MAR	74	1200	C
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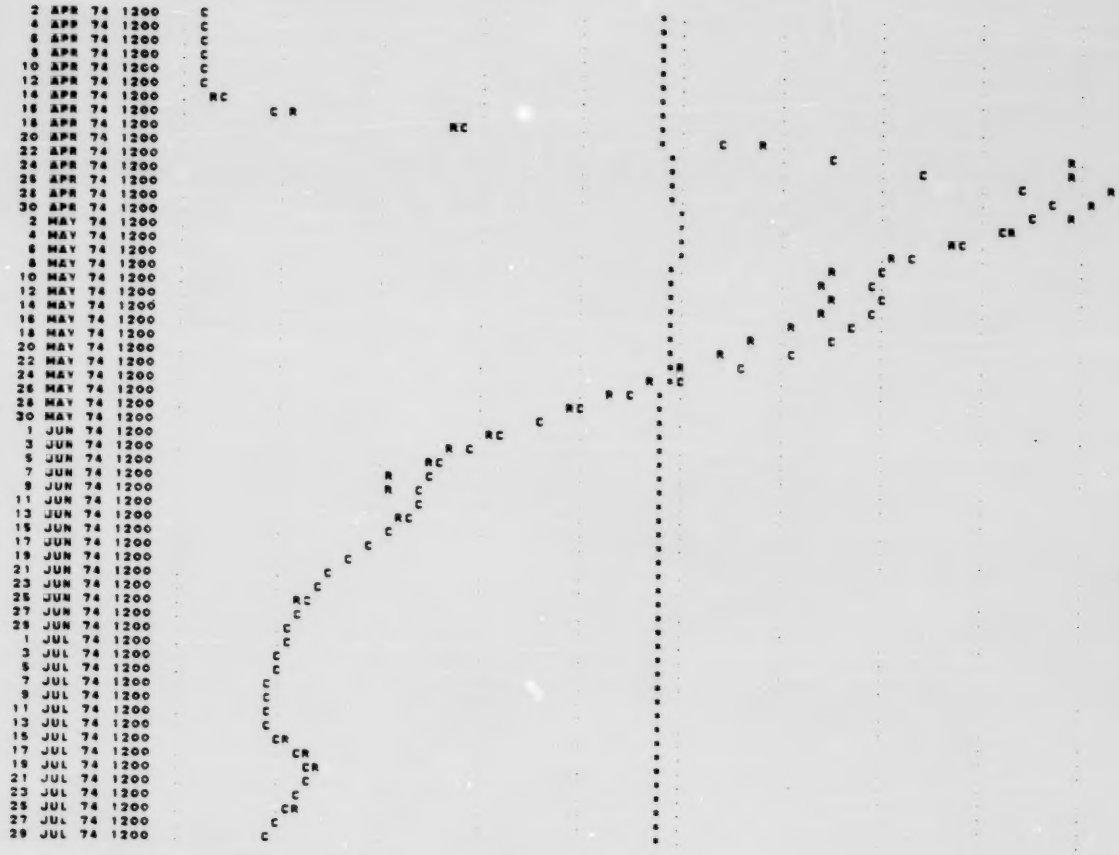
27	MAR	74	1200	C
29	MAR	74	1200	C
31	MAR	74	1200	C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6 APR 74 1200
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24 APR 74 1200
26 APR 74 1200
28 APR 74 1200
30 APR 74 1200
2 MAY 74 1200
4 MAY 74 1200
6 MAY 74 1200
8 MAY 74 1200
10 MAY 74 1200
12 MAY 74 1200
14 MAY 74 1200
16 MAY 74 1200
18 MAY 74 1200
20 MAY 74 1200
22 MAY 74 1200
24 MAY 74 1200
26 MAY 74 1200
28 MAY 74 1200
30 MAY 74 1200
1 JUN 74 1200
3 JUN 74 1200
5 JUN 74 1200
7 JUN 74 1200
9 JUN 74 1200
11 JUN 74 1200
13 JUN 74 1200
15 JUN 74 1200
17 JUN 74 1200
19 JUN 74 1200
21 JUN 74 1200
23 JUN 74 1200
25 JUN 74 1200
27 JUN 74 1200
29 JUN 74 1200
1 JUL 74 1200
3 JUL 74 1200
5 JUL 74 1200
7 JUL 74 1200
9 JUL 74 1200
11 JUL 74 1200
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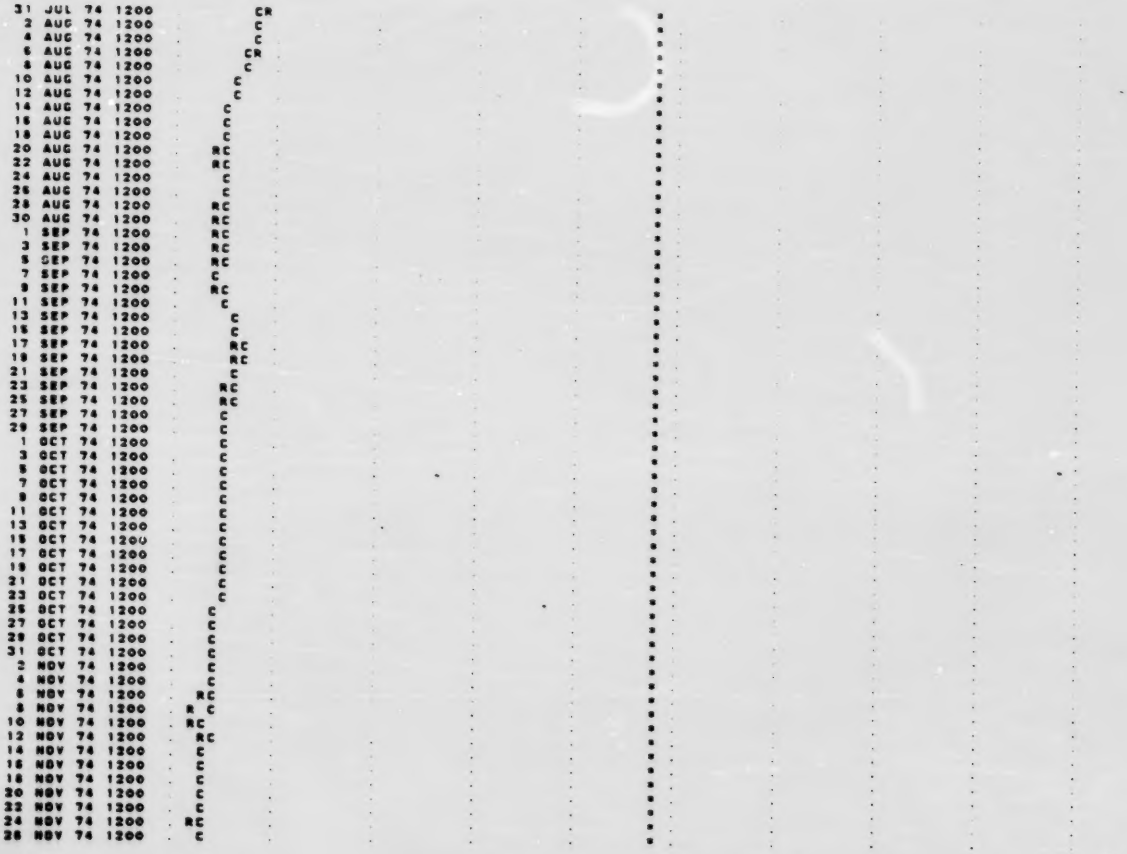
21 JUL 74 1200
23 JUL 74 1200
25 JUL 74 1200
27 JUL 74 1200
29 JUL 74 1200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2 AUG 74 1200
4 AUG 74 1200
6 AUG 74 1200
8 AUG 74 1200
10 AUG 74 1200
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14 AUG 74 1200
16 AUG 74 1200
18 AUG 74 1200
20 AUG 74 1200
22 AUG 74 1200
24 AUG 74 1200
26 AUG 74 1200
28 AUG 74 1200
30 AUG 74 1200
1 SEP 74 1200
3 SEP 74 1200
5 SEP 74 1200
7 SEP 74 1200
9 SEP 74 1200
11 SEP 74 1200
13 SEP 74 1200
15 SEP 74 1200
17 SEP 74 1200
19 SEP 74 1200
21 SEP 74 1200
23 SEP 74 1200
25 SEP 74 1200
27 SEP 74 1200
29 SEP 74 1200
1 OCT 74 1200
3 OCT 74 1200
5 OCT 74 1200
7 OCT 74 1200
9 OCT 74 1200
11 OCT 74 1200
13 OCT 74 1200
15 OCT 74 1200
17 OCT 74 1200
19 OCT 74 1200
21 OCT 74 1200
23 OCT 74 1200
25 OCT 74 1200
27 OCT 74 1200
29 OCT 74 1200
31 OCT 74 1200
2 NOV 74 1200
4 NOV 74 1200
6 NOV 74 1200
8 NOV 74 1200
10 NOV 74 1200
12 NOV 74 1200
14 NOV 74 1200
16 NOV 74 1200
18 NOV 74 1200
20 NOV 74 1200
22 NOV 74 1200
24 NOV 74 1200
26 NOV 74 1200

```
28 NOV 74 1200  .RC
30 NOV 74 1200  .RC
 2 DEC 74 1200  .RC
 4 DEC 74 1200   RC
 6 DEC 74 1200  .RC
 8 DEC 74 1200  .RC
10 DEC 74 1200  .RC
12 DEC 74 1200   RC
14 DEC 74 1200  .RC
16 DEC 74 1200   RC
18 DEC 74 1200   RC
20 DEC 74 1200   RC
22 DEC 74 1200    C
24 DEC 74 1200    C
26 DEC 74 1200  .C
28 DEC 74 1200  .C
30 DEC 74 1200    C
 1 JAN 75 1200    C
 3 JAN 75 1200   RC
 5 JAN 75 1200   RC
 7 JAN 75 1200  .RC
 9 JAN 75 1200  .RC
11 JAN 75 1200  .RC
13 JAN 75 1200  .RC
15 JAN 75 1200  .RC
17 JAN 75 1200  .RC
19 JAN 75 1200  .RC
21 JAN 75 1200   RC
23 JAN 75 1200  .RC
25 JAN 75 1200  .C
27 JAN 75 1200    C
29 JAN 75 1200  .C
31 JAN 75 1200    C
 2 FEB 75 1200    C
 4 FEB 75 1200   RC
 6 FEB 75 1200  .RC
 8 FEB 75 1200  .RC
10 FEB 75 1200  .C
12 FEB 75 1200    C
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16 FEB 75 1200  .C
18 FEB 75 1200  .C
20 FEB 75 1200    C
22 FEB 75 1200  .C
24 FEB 75 1200   RC
26 FEB 75 1200   RC
28 FEB 75 1200    C
 2 MAR 75 1200    C
 4 MAR 75 1200  .C
 6 MAR 75 1200  .C
 8 MAR 75 1200   RC
10 MAR 75 1200  .RC
12 MAR 75 1200   RC
14 MAR 75 1200   RC
16 MAR 75 1200   RC
18 MAR 75 1200  .C
20 MAR 75 1200  .C
22 MAR 75 1200  .C
24 MAR 75 1200  .C
26 MAR 75 1200  .C
```

```
24 MAR 75 1200  .RC
30 MAR 75 1200  .RC
 1 APR 75 1200  ..RC
 3 APR 75 1200   RC
 5 APR 75 1200  .RC
 7 APR 75 1200  .RC
 9 APR 75 1200   RC
11 APR 75 1200  .RC
13 APR 75 1200  .C
15 APR 75 1200  .C
17 APR 75 1200  .RC
19 APR 75 1200        C
21 APR 75 1200          C R
23 APR 75 1200              C   R
25 APR 75 1200                C       R
27 APR 75 1200                  C     R   R
29 APR 75 1200                      C     R
 1 MAY 75 1200                        C   R
 3 MAY 75 1200                        C R
 5 MAY 75 1200                        CR
 7 MAY 75 1200                       C
 9 MAY 75 1200                     C
11 MAY 75 1200                    C
13 MAY 75 1200                  RC
15 MAY 75 1200                 R C
17 MAY 75 1200                 RC
19 MAY 75 1200                RC
21 MAY 75 1200               RC
23 MAY 75 1200              R C
25 MAY 75 1200              RC
27 MAY 75 1200              RC
29 MAY 75 1200               RC
31 MAY 75 1200               RC
 2 JUN 75 1200              R C
 4 JUN 75 1200              R C
 6 JUN 75 1200               RC
 8 JUN 75 1200                RC
10 JUN 75 1200               RC
12 JUN 75 1200              RC
14 JUN 75 1200              RC
16 JUN 75 1200             RC
18 JUN 75 1200            RC
20 JUN 75 1200           RC
22 JUN 75 1200          RC
24 JUN 75 1200         RC
26 JUN 75 1200        R C
28 JUN 75 1200          RC
30 JUN 75 1200                C
 2 JUL 75 1200                  R C
 4 JUL 75 1200                    R C
 6 JUL 75 1200                      R   C
 8 JUL 75 1200                        R   C
10 JUL 75 1200                      R C
12 JUL 75 1200                    R   C
14 JUL 75 1200                R   C
16 JUL 75 1200              R   C
18 JUL 75 1200              R C
20 JUL 75 1200               R C
22 JUL 75 1200                R   C
24 JUL 75 1200                R   C
```

```
26 JUL 75 1200                    R C
28 JUL 75 1200                  R C
30 JUL 75 1200                RC
 1 AUG 75 1200              R C
 3 AUG 75 1200            .R C
 5 AUG 75 1200            .RC
 7 AUG 75 1200           RC
 9 AUG 75 1200           RC
11 AUG 75 1200           RC
13 AUG 75 1200           C
15 AUG 75 1200          RC
17 AUG 75 1200          RC
19 AUG 75 1200          C
21 AUG 75 1200         RC
23 AUG 75 1200         C
25 AUG 75 1200         C
27 AUG 75 1200         C
29 AUG 75 1200         C
31 AUG 75 1200         C
 2 SEP 75 1200          RC
 4 SEP 75 1200            .C
 6 SEP 75 1200            RC
 8 SEP 75 1200              C
10 SEP 75 1200            .RC
12 SEP 75 1200           RC
14 SEP 75 1200          RC
16 SEP 75 1200         RC
18 SEP 75 1200         C
20 SEP 75 1200        RC
22 SEP 75 1200        C
24 SEP 75 1200       C
26 SEP 75 1200       C
28 SEP 75 1200       C
30 SEP 75 1200      RC
 2 OCT 75 1200      C
 4 OCT 75 1200      C
 6 OCT 75 1200      C
 8 OCT 75 1200      C
10 OCT 75 1200      C
12 OCT 75 1200      C
14 OCT 75 1200      C
16 OCT 75 1200      C
18 OCT 75 1200     RC
20 OCT 75 1200     RC
22 OCT 75 1200     C
24 OCT 75 1200     C
26 OCT 75 1200     C
28 OCT 75 1200     C
30 OCT 75 1200     C
 1 NOV 75 1200     C
 3 NOV 75 1200     C
 5 NOV 75 1200    C
 7 NOV 75 1200    C
 9 NOV 75 1200    C
11 NOV 75 1200    C
13 NOV 75 1200    C
15 NOV 75 1200    C
17 NOV 75 1200    C
19 NOV 75 1200   RC
21 NOV 75 1200   RC
```

```
23 NOV 75 1200   RC
25 NOV 75 1200   RC
27 NOV 75 1200   RC
29 NOV 75 1200   RC
 1 DEC 75 1200   RC
 3 DEC 75 1200   RC
 5 DEC 75 1200   RC
 7 DEC 75 1200   RC
 9 DEC 75 1200   RC
11 DEC 75 1200   RC
13 DEC 75 1200   RC
15 DEC 75 1200   RC
17 DEC 75 1200   RC
19 DEC 75 1200   C
21 DEC 75 1200   C
23 DEC 75 1200   C
25 DEC 75 1200   C
27 DEC 75 1200   C
29 DEC 75 1200   C
31 DEC 75 1200   C
```

```
                                        PLOT      STATION NAME                                   STATION
                                      CHARACTER                                                 NUMBER CONTROL

                                          C-CALC  BEAVER RIVER FLOW AT COLD LAKE                 726 0   0
                                          R-BEAVER R  AT COLD LAKE 08AD005                       52 6   0
FLOW CFS            0       1500.     3000      4500.      6000      7500      9000.     10500     12000.     13500      15000
                                                  *-DUMMY RES  (DIFF) AT BEAVER RIVER AT COLD LA      726 2   E
ELEV FT.          -5.        -4.       -3         -2        -1        -0         1         2         3.         4          5
 1 JAN 75 1200     C                                                   *
 3 JAN 75 1200     C                                                   *
 5 JAN 75 1200     C                                                   *
 7 JAN 75 1200     C                                                   *
 9 JAN 75 1200     C                                                   *
11 JAN 75 1200     C                                                   *
13 JAN 75 1200     C                                                   *
15 JAN 75 1200     C                                                   *
17 JAN 75 1200     C                                                   *
19 JAN 75 1200     C                                                   *
21 JAN 75 1200     C                                                   *
23 JAN 75 1200     C                                                   *
25 JAN 75 1200     C                                                   *
27 JAN 75 1200     C                                                   *
29 JAN 75 1200     C                                                   *
31 JAN 75 1200     C                                                   *
 2 FEB 75 1200     C                                                   *
 4 FEB 75 1200     C                                                   *
 6 FEB 75 1200     C                                                   *
 8 FEB 75 1200     C                                                   *
10 FEB 75 1200     C                                                   *
12 FEB 75 1200     C                                                   *
14 FEB 75 1200     C                                                   *
16 FEB 75 1200     C                                                   *
18 FEB 75 1200     C                                                   *
20 FEB 75 1200     C                                                   *
22 FEB 75 1200     C                                                   *
24 FEB 75 1200     C                                                   *
26 FEB 75 1200     C                                                   *
28 FEB 75 1200    .RC                                                  *
 1 MAR 75 1200    .RC                                                  *
 3 MAR 75 1200    .RC                                                  *
 5 MAR 75 1200    .RC                                                  *
 7 MAR 75 1200    .RC                                                  *
 9 MAR 75 1200    .RC                                                  *
11 MAR 75 1200    .RC                                                  *
13 MAR 75 1200    .RC                                                  *
15 MAR 75 1200    .RC                                                  *
17 MAR 75 1200    .RC                                                  *
19 MAR 75 1200    .RC                                                  *
21 MAR 75 1200    .RC                                                  *
23 MAR 75 1200    .RC                                                  *
25 MAR 75 1200     C                                                   *
27 MAR 75 1200     C                                                   *
29 MAR 75 1200     C                                                   *
31 MAR 75 1200     C                                                   *
 2 APR 75 1200      C                                                  *
 4 APR 75 1200      CR                                                 *
 6 APR 75 1200        CR                                               *
 8 APR 75 1200          C                                              *
10 APR 75 1200            C.R                                           *
```

```
12 APR 76 1200          C R
14 APR 76 1200           CR
16 APR 76 1200          CR
18 APR 76 1200          C
20 APR 76 1200         C
22 APR 76 1200        C
24 APR 76 1200        C
26 APR 76 1200       C
28 APR 76 1200       C
30 APR 76 1200      C
 2 MAY 76 1200      C
 4 MAY 76 1200     C
 6 MAY 76 1200    RC
 8 MAY 76 1200    C
10 MAY 76 1200   RC
12 MAY 76 1200   C
14 MAY 76 1200   C
16 MAY 76 1200  RC
18 MAY 76 1200  C
20 MAY 76 1200  C
22 MAY 76 1200  CR
24 MAY 76 1200  C
26 MAY 76 1200  C
28 MAY 76 1200  C
30 MAY 76 1200  C
 1 JUN 76 1200  C
 3 JUN 76 1200  C
 5 JUN 76 1200  C
 7 JUN 76 1200  C
 9 JUN 76 1200  C
11 JUN 76 1200  C
13 JUN 76 1200  C
15 JUN 76 1200 CR
17 JUN 76 1200 C
19 JUN 76 1200 C
21 JUN 76 1200 CR
23 JUN 76 1200  C
25 JUN 76 1200   C R
27 JUN 76 1200      CR
29 JUN 76 1200        C
 1 JUL 76 1200          RC
 3 JUL 76 1200           C
 5 JUL 76 1200         RC
 7 JUL 76 1200        RC
 9 JUL 76 1200       C
11 JUL 76 1200      RC
13 JUL 76 1200        RC
15 JUL 76 1200              RC
17 JUL 76 1200                R   C
19 JUL 76 1200                 R    C
21 JUL 76 1200                 R   C
23 JUL 76 1200                R  C
25 JUL 76 1200             RC
27 JUL 76 1200           RC
29 JUL 76 1200         RC
31 JUL 76 1200       C
 2 AUG 76 1200      RC
 4 AUG 76 1200     RC
 6 AUG 76 1200    RC
 8 AUG 76 1200    C
```

```
10 AUG 76 1200    C
12 AUG 76 1200   RC
14 AUG 76 1200   RC
16 AUG 76 1200   C
18 AUG 76 1200   C
20 AUG 76 1200   C
22 AUG 76 1200   C
24 AUG 76 1200   C
26 AUG 76 1200  RC
28 AUG 76 1200  RC
30 AUG 76 1200   C
 1 SEP 76 1200    C
 3 SEP 76 1200    C
 5 SEP 76 1200    C
 7 SEP 76 1200    C
 9 SEP 76 1200    C
11 SEP 76 1200    C
13 SEP 76 1200    C
15 SEP 76 1200    C
17 SEP 76 1200    C
19 SEP 76 1200   C
21 SEP 76 1200   C
23 SEP 76 1200  C
25 SEP 76 1200  C
27 SEP 76 1200  C
29 SEP 76 1200 C
 1 OCT 76 1200 C
 3 OCT 76 1200 C
 5 OCT 76 1200 C
 7 OCT 76 1200 C
 9 OCT 76 1200 C
11 OCT 76 1200 RC
13 OCT 76 1200 C
15 OCT 76 1200 C
17 OCT 76 1200 C
19 OCT 76 1200 C
21 OCT 76 1200 C
23 OCT 76 1200 RC
25 OCT 76 1200 RC
27 OCT 76 1200 C
29 OCT 76 1200 C
31 OCT 76 1200 C
 2 NOV 76 1200 C
 4 NOV 76 1200 C
 6 NOV 76 1200 C
 8 NOV 76 1200 C
10 NOV 76 1200 C
12 NOV 76 1200 C
14 NOV 76 1200 C
16 NOV 76 1200 C
18 NOV 76 1200 RC
20 NOV 76 1200 RC
22 NOV 76 1200 RC
24 NOV 76 1200 RC
26 NOV 76 1200 RC
28 NOV 76 1200 RC
30 NOV 76 1200 RC
 2 DEC 76 1200 RC
 4 DEC 76 1200 RC
 6 DEC 76 1200 RC
```

```
 8 DEC 76 1200   RC
10 DEC 76 1200   RC
12 DEC 76 1200   RC
14 DEC 76 1200   RC
16 DEC 76 1200   RC
18 DEC 76 1200   RC
20 DEC 76 1200   RC
22 DEC 76 1200   RC
24 DEC 76 1200   RC
26 DEC 76 1200   RC
28 DEC 76 1200   C
30 DEC 76 1200   C
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 3 JAN 77 1200   C
 5 JAN 77 1200   C
 7 JAN 77 1200   C
 9 JAN 77 1200   C
11 JAN 77 1200   C
13 JAN 77 1200   C
15 JAN 77 1200   C
17 JAN 77 1200   C
19 JAN 77 1200   C
21 JAN 77 1200   C
23 JAN 77 1200   C
25 JAN 77 1200   C
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29 JAN 77 1200   C
31 JAN 77 1200   C
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 4 FEB 77 1200   C
 6 FEB 77 1200   C
 8 FEB 77 1200   C
10 FEB 77 1200   C
12 FEB 77 1200   C
14 FEB 77 1200   C
16 FEB 77 1200   C
18 FEB 77 1200   C
20 FEB 77 1200   C
22 FEB 77 1200   C
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26 FEB 77 1200   C
28 FEB 77 1200   C
 2 MAR 77 1200   C
 4 MAR 77 1200   C
 6 MAR 77 1200   C
 8 MAR 77 1200   C
10 MAR 77 1200   C
12 MAR 77 1200   C
14 MAR 77 1200   C
16 MAR 77 1200   C
18 MAR 77 1200   C
20 MAR 77 1200   C
22 MAR 77 1200   C
24 MAR 77 1200   C
26 MAR 77 1200   C
28 MAR 77 1200   C
30 MAR 77 1200   C
 1 APR 77 1200   C
 3 APR 77 1200   C
 5 APR 77 1200   C
```

```
 7 APR 77 1200   C
 9 APR 77 1200   RC
11 APR 77 1200   R C
13 APR 77 1200    R  C
15 APR 77 1200     R        C
17 APR 77 1200              C   R
19 APR 77 1200              C  R
21 APR 77 1200              CR
23 APR 77 1200            CR
25 APR 77 1200          CR
27 APR 77 1200        CR
29 APR 77 1200        CR
 1 MAY 77 1200      CR
 3 MAY 77 1200      CR
 5 MAY 77 1200      CR
 7 MAY 77 1200      CR
 9 MAY 77 1200      C
11 MAY 77 1200      C
13 MAY 77 1200     CR
15 MAY 77 1200      C
17 MAY 77 1200       C
19 MAY 77 1200          CR
21 MAY 77 1200             CR
23 MAY 77 1200              C
25 MAY 77 1200             CR
27 MAY 77 1200              C
29 MAY 77 1200             CR
31 MAY 77 1200              CR
 2 JUN 77 1200              CR
 4 JUN 77 1200             CR
 6 JUN 77 1200           CR
 8 JUN 77 1200         C
10 JUN 77 1200        C
12 JUN 77 1200      C
14 JUN 77 1200      C
16 JUN 77 1200     C
18 JUN 77 1200    RC
20 JUN 77 1200    RC
22 JUN 77 1200   RC
24 JUN 77 1200   RC
26 JUN 77 1200   RC
28 JUN 77 1200   C
30 JUN 77 1200   C
 2 JUL 77 1200  RC
 4 JUL 77 1200  RC
 6 JUL 77 1200  C
 8 JUL 77 1200  C
10 JUL 77 1200  CR
12 JUL 77 1200   C
14 JUL 77 1200   C
16 JUL 77 1200    E
18 JUL 77 1200    E
20 JUL 77 1200    E
22 JUL 77 1200    E
24 JUL 77 1200     E
26 JUL 77 1200    RE
28 JUL 77 1200     E
30 JUL 77 1200    CR
 1 AUG 77 1200     E
 3 AUG 77 1200     CR
```

5	AUG	77	1200	CR
7	AUG	77	1200	C
9	AUG	77	1200	C
11	AUG	77	1200	C
13	AUG	77	1200	CR
15	AUG	77	1200	C
17	AUG	77	1200	CR
19	AUG	77	1200	C
21	AUG	77	1200	C
23	AUG	77	1200	C
25	AUG	77	1200	C
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10	SEP	77	1200	C
12	SEP	77	1200	C
14	SEP	77	1200	C
16	SEP	77	1200	C
18	SEP	77	1200	C
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22	SEP	77	1200	CR
24	SEP	77	1200	CR
26	SEP	77	1200	CR
28	SEP	77	1200	CR
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4	OCT	77	1200	CR
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12	OCT	77	1200	CR
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18	OCT	77	1200	C
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26	OCT	77	1200	C
28	OCT	77	1200	C
30	OCT	77	1200	C
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7	NOV	77	1200	CR
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11	NOV	77	1200	C
13	NOV	77	1200	C
15	NOV	77	1200	RC
17	NOV	77	1200	RC
19	NOV	77	1200	C
21	NOV	77	1200	RC
23	NOV	77	1200	RC
25	NOV	77	1200	RC
27	NOV	77	1200	RC
29	NOV	77	1200	RC
1	DEC	77	1200	RC
3	DEC	77	1200	RC
5	DEC	77	1200	RC
7	DEC	77	1200	RC
9	DEC	77	1200	RC
11	DEC	77	1200	RC
13	DEC	77	1200	RC
15	DEC	77	1200	RC
17	DEC	77	1200	RC
19	DEC	77	1200	RC
21	DEC	77	1200	RC
23	DEC	77	1200	RC
25	DEC	77	1200	RC
27	DEC	77	1200	RC
29	DEC	77	1200	RC
31	DEC	77	1200	RC
2	JAN	78	1200	RC
4	JAN	78	1200	RC
6	JAN	78	1200	RC
8	JAN	78	1200	RC
10	JAN	78	1200	RC
12	JAN	78	1200	C
14	JAN	78	1200	C
16	JAN	78	1200	C
18	JAN	78	1200	C
20	JAN	78	1200	C
22	JAN	78	1200	C
24	JAN	78	1200	C
26	JAN	78	1200	C
28	JAN	78	1200	C
30	JAN	78	1200	C
1	FEB	78	1200	C
3	FEB	78	1200	C
5	FEB	78	1200	C
7	FEB	78	1200	C
9	FEB	78	1200	C
11	FEB	78	1200	C
13	FEB	78	1200	C
15	FEB	78	1200	C
17	FEB	78	1200	C
19	FEB	78	1200	C
21	FEB	78	1200	C
23	FEB	78	1200	C
25	FEB	78	1200	C
27	FEB	78	1200	C
1	MAR	78	1200	C
3	MAR	78	1200	C
5	MAR	78	1200	C
7	MAR	78	1200	C
9	MAR	78	1200	C
11	MAR	78	1200	C
13	MAR	78	1200	C
15	MAR	78	1200	C
17	MAR	78	1200	C
19	MAR	78	1200	C
21	MAR	78	1200	C
23	MAR	78	1200	C
25	MAR	78	1200	C
27	MAR	78	1200	C
29	MAR	78	1200	C
31	MAR	78	1200	C

```
 2 APR 78 1200   RC
 4 APR 78 1200    RC
 6 APR 78 1200    RC
 8 APR 78 1200      CR
10 APR 78 1200      CR
12 APR 78 1200        C
14 APR 78 1200         C
16 APR 78 1200        RC
18 APR 78 1200       R C
20 APR 78 1200        RC
22 APR 78 1200         C
24 APR 78 1200        CR
26 APR 78 1200         CR
28 APR 78 1200          RC
30 APR 78 1200           C
 2 MAY 78 1200          RC
 4 MAY 78 1200          RC
 6 MAY 78 1200          RC
 8 MAY 78 1200         R C
10 MAY 78 1200         RC
12 MAY 78 1200         RC
14 MAY 78 1200        RC
16 MAY 78 1200        RC
18 MAY 78 1200       RC
20 MAY 78 1200       RC
22 MAY 78 1200      RC
24 MAY 78 1200      RC
26 MAY 78 1200      RC
28 MAY 78 1200       R C
30 MAY 78 1200           R C
 1 JUN 78 1200                       RC
 3 JUN 78 1200                            R    C
 5 JUN 78 1200                                  CR
 7 JUN 78 1200                            C    R
 9 JUN 78 1200                         CR
11 JUN 78 1200                      CR
13 JUN 78 1200                  CR
15 JUN 78 1200                C
17 JUN 78 1200               C
19 JUN 78 1200              C
21 JUN 78 1200             RC
23 JUN 78 1200          RC
25 JUN 78 1200         RC
27 JUN 78 1200        RC
29 JUN 78 1200        C
 1 JUL 78 1200       C
 3 JUL 78 1200      RC
 5 JUL 78 1200      C
 7 JUL 78 1200     C
 9 JUL 78 1200    RC
11 JUL 78 1200    C
13 JUL 78 1200   RC
15 JUL 78 1200   C
17 JUL 78 1200   C
19 JUL 78 1200   C
21 JUL 78 1200  C
23 JUL 78 1200  C
25 JUL 78 1200  RC
27 JUL 78 1200  C
29 JUL 78 1200  C

31 JUL 78 1200  C
 2 AUG 78 1200  C
 4 AUG 78 1200  C
 6 AUG 78 1200  C
 8 AUG 78 1200 C
10 AUG 78 1200 C
12 AUG 78 1200 C
14 AUG 78 1200 C
16 AUG 78 1200 C
18 AUG 78 1200 C
20 AUG 78 1200 C
22 AUG 78 1200 C
24 AUG 78 1200 C
26 AUG 78 1200 C
28 AUG 78 1200 C
30 AUG 78 1200 C
 1 SEP 78 1200 C
 3 SEP 78 1200 C
 5 SEP 78 1200 C
 7 SEP 78 1200 C
 9 SEP 78 1200 C
11 SEP 78 1200   CR
13 SEP 78 1200     CR
15 SEP 78 1200      RC
17 SEP 78 1200        C
19 SEP 78 1200         CR
21 SEP 78 1200            C
23 SEP 78 1200             C
25 SEP 78 1200            CR
27 SEP 78 1200           CR
29 SEP 78 1200          CR
 1 OCT 78 1200         C
 3 OCT 78 1200        C
 5 OCT 78 1200       C
 7 OCT 78 1200      CR
 9 OCT 78 1200      C
11 OCT 78 1200     C
13 OCT 78 1200    C
15 OCT 78 1200    C
17 OCT 78 1200   C
19 OCT 78 1200   C
21 OCT 78 1200  CR
23 OCT 78 1200  C
25 OCT 78 1200  C
27 OCT 78 1200  C
29 OCT 78 1200  CR
31 OCT 78 1200  C
 3 NOV 78 1200  C
 4 NOV 78 1200  C
 6 NOV 78 1200  C
 8 NOV 78 1200  C
10 NOV 78 1200 RC
12 NOV 78 1200 C
14 NOV 78 1200 C
16 NOV 78 1200 C
18 NOV 78 1200 RC
20 NOV 78 1200 RC
22 NOV 78 1200 R C
24 NOV 78 1200 R C
26 NOV 78 1200 R C
```

28	NOV	78	1200	R C
30	NOV	78	1200	R C
2	DEC	78	1200	R C
4	DEC	78	1200	R C
6	DEC	78	1200	R C
8	DEC	78	1200	RC
10	DEC	78	1200	RC
12	DEC	78	1200	RC
14	DEC	78	1200	RC
16	DEC	78	1200	C
18	DEC	78	1200	C
20	DEC	78	1200	C
22	DEC	78	1200	C
24	DEC	78	1200	C
26	DEC	78	1200	C
28	DEC	78	1200	C
30	DEC	78	1200	C
1	JAN	79	1200	C
3	JAN	79	1200	C
5	JAN	79	1200	C
7	JAN	79	1200	C
9	JAN	79	1200	RC
11	JAN	79	1200	RC
13	JAN	79	1200	RC
15	JAN	79	1200	RC
17	JAN	79	1200	RC
19	JAN	79	1200	RC
21	JAN	79	1200	RC
23	JAN	79	1200	RC
25	JAN	79	1200	RC
27	JAN	79	1200	RC
29	JAN	79	1200	RC
31	JAN	79	1200	RC
2	FEB	79	1200	RC
4	FEB	79	1200	RC
6	FEB	79	1200	RC
8	FEB	79	1200	RC
10	FEB	79	1200	RC
12	FEB	79	1200	C
14	FEB	79	1200	C
16	FEB	79	1200	C
18	FEB	79	1200	C
20	FEB	79	1200	C
22	FEB	79	1200	C
24	FEB	79	1200	C
26	FEB	79	1200	C
28	FEB	79	1200	C
2	MAR	79	1200	C
4	MAR	79	1200	C
6	MAR	79	1200	C
8	MAR	79	1200	C
10	MAR	79	1200	C
12	MAR	79	1200	C
14	MAR	79	1200	C
16	MAR	79	1200	CR
18	MAR	79	1200	C
20	MAR	79	1200	C
22	MAR	79	1200	C
24	MAR	79	1200	C
26	MAR	79	1200	CR
28	MAR	79	1200	C
30	MAR	79	1200	RC
1	APR	79	1200	C
3	APR	79	1200	C
5	APR	79	1200	C
7	APR	79	1200	C
9	APR	79	1200	C
11	APR	79	1200	C
13	APR	79	1200	C
15	APR	79	1200	C
17	APR	79	1200	C
19	APR	79	1200	C R
21	APR	79	1200	C R
23	APR	79	1200	C R
25	APR	79	1200	R C
27	APR	79	1200	C R
29	APR	79	1200	C R
1	MAY	79	1200	C R
3	MAY	79	1200	C R
5	MAY	79	1200	C R
7	MAY	79	1200	C R
9	MAY	79	1200	C R
11	MAY	79	1200	C R
13	MAY	79	1200	C R
15	MAY	79	1200	C R
17	MAY	79	1200	CR
19	MAY	79	1200	CR
21	MAY	79	1200	CR
23	MAY	79	1200	C R
25	MAY	79	1200	C R
27	MAY	79	1200	C R
29	MAY	79	1200	C
31	MAY	79	1200	C
2	JUN	79	1200	C
4	JUN	79	1200	RC
6	JUN	79	1200	C
8	JUN	79	1200	C
10	JUN	79	1200	C
12	JUN	79	1200	C
14	JUN	79	1200	C
16	JUN	79	1200	C
18	JUN	79	1200	C
20	JUN	79	1200	C
22	JUN	79	1200	C
24	JUN	79	1200	C
26	JUN	79	1200	RC
28	JUN	79	1200	RC
30	JUN	79	1200	RC
2	JUL	79	1200	RC
4	JUL	79	1200	RC
6	JUL	79	1200	C
8	JUL	79	1200	RC
10	JUL	79	1200	C
12	JUL	79	1200	RC
14	JUL	79	1200	C
16	JUL	79	1200	C
18	JUL	79	1200	RC
20	JUL	79	1200	C
22	JUL	79	1200	C
24	JUL	79	1200	C

```
26 JUL 79 1200          C
28 JUL 79 1200         E
30 JUL 79 1200        RE
 1 AUG 79 1200        C
 3 AUG 79 1200       C
 5 AUG 79 1200       C
 7 AUG 79 1200       C
 9 AUG 79 1200       C
11 AUG 79 1200      RC
13 AUG 79 1200      RC
15 AUG 79 1200      C
17 AUG 79 1200      C
19 AUG 79 1200     C
21 AUG 79 1200     C
23 AUG 79 1200    RC
25 AUG 79 1200    C
27 AUG 79 1200    C
29 AUG 79 1200    C
31 AUG 79 1200    C
 2 SEP 79 1200    C
 4 SEP 79 1200    C
 6 SEP 79 1200    C
 8 SEP 79 1200    C
10 SEP 79 1200    CR
12 SEP 79 1200     E
14 SEP 79 1200      E
16 SEP 79 1200      CR
18 SEP 79 1200       E
20 SEP 79 1200       C
22 SEP 79 1200      C
24 SEP 79 1200      C
26 SEP 79 1200      C
28 SEP 79 1200     C
30 SEP 79 1200     C
 2 OCT 79 1200     C
 4 OCT 79 1200     C
 6 OCT 79 1200     C
 8 OCT 79 1200     C
10 OCT 79 1200    RC
12 OCT 79 1200    C
14 OCT 79 1200    C
16 OCT 79 1200    C
18 OCT 79 1200    C
20 OCT 79 1200    C
22 OCT 79 1200    C
24 OCT 79 1200    C
26 OCT 79 1200    C
28 OCT 79 1200    C
30 OCT 79 1200   CR
 1 NOV 79 1200   CP
 3 NOV 79 1200   C
 5 NOV 79 1200   C
 7 NOV 79 1200   C
 9 NOV 79 1200   C
11 NOV 79 1200   C
13 NOV 79 1200   C
15 NOV 79 1200   C
17 NOV 79 1200   C
19 NOV 79 1200   C
21 NOV 79 1200   C

23 NOV 79 1200  RC
25 NOV 79 1200  RC
27 NOV 79 1200  RC
29 NOV 79 1200  RC
 1 DEC 79 1200  RC
 3 DEC 79 1200  RC
 5 DEC 79 1200  RC
 7 DEC 79 1200  RC
 9 DEC 79 1200  RC
11 DEC 79 1200  RC
13 DEC 79 1200  RC
15 DEC 79 1200  RC
17 DEC 79 1200  RC
19 DEC 79 1200  RC
21 DEC 79 1200  RC
23 DEC 79 1200  RC
25 DEC 79 1200  C
27 DEC 79 1200  C
29 DEC 79 1200  C
31 DEC 79 1200  C
```

```
                                                  CHARACTER                                   NUMBER CONTROL

                                                  C-CALC. BEAVER RIVER FLOW AT COLD LAKE             726.0   O
                                                  R-BEAVER R. AT COLD LAKE 06AD005                    62.6   O
FLOW CFS          0.        1500.      3000.        4500.      6000.      7500.      9000.      10500.     12000.     13500.     15000
                                                  *-DUMMY RES  (DIFF) AT BEAVER RIVER AT COLD LA     726.2   E
ELEV FT.         -5          -4         -3          -2         -1         -0          1          2          3          4          5
  1 JAN 80 1200  .C                                                 *
  3 JAN 80 1200  .C                                                 *
  5 JAN 80 1200  .C                                                 *
  7 JAN 80 1200  .C                                                 *
  9 JAN 80 1200  .C                                                 *
 11 JAN 80 1200  .C                                                 *
 13 JAN 80 1200  .C                                                 *
 15 JAN 80 1200  .C                                                 *
 17 JAN 80 1200  .C                                                 *
 19 JAN 80 1200  .C                                                 *
 21 JAN 80 1200  .C                                                 *
 23 JAN 80 1200  .C                                                 *
 25 JAN 80 1200  .C                                                 *
 27 JAN 80 1200  .C                                                 *
 29 JAN 80 1200  .C                                                 *
 31 JAN 80 1200  .C                                                 *
  2 FEB 80 1200  .C                                                 *
  4 FEB 80 1200  .C                                                 *
  6 FEB 80 1200  .C                                                 *
  8 FEB 80 1200  .C                                                 *
 10 FEB 80 1200  .C                                                 *
 12 FEB 80 1200  .C                                                 *
 14 FEB 80 1200  .C                                                 *
 16 FEB 80 1200  .C                                                 *
 18 FEB 80 1200  .C                                                 *
 20 FEB 80 1200  .C                                                 *
 22 FEB 80 1200  .C                                                 *
 24 FEB 80 1200  .C                                                 *
 26 FEB 80 1200  .C                                                 *
 28 FEB 80 1200  .C                                                 *
  1 MAR 80 1200  .C                                                 *
  3 MAR 80 1200  .C                                                 *
  5 MAR 80 1200  .C                                                 *
  7 MAR 80 1200  .C                                                 *
  9 MAR 80 1200  .C                                                 *
 11 MAR 80 1200  .C                                                 *
 13 MAR 80 1200  .C                                                 *
 15 MAR 80 1200  .C                                                 *
 17 MAR 80 1200  .C                                                 *
 19 MAR 80 1200  .C                                                 *
 21 MAR 80 1200  .C                                                 *
 23 MAR 80 1200  .C                                                 *
 25 MAR 80 1200  .C                                                 *
 27 MAR 80 1200  .C                                                 *
 29 MAR 80 1200  .C                                                 *
 31 MAR 80 1200  .C                                                 *
  2 APR 80 1200  .CR                                                *
  4 APR 80 1200  .C                                                 *
  6 APR 80 1200  .C                                                 *
  8 APR 80 1200  .  CR                                              *
 10 APR 80 1200  .     C R                                          *


 12 APR 80 1200  .       C .R                                       *
 14 APR 80 1200  .          R C                                     *
 16 APR 80 1200  .        C               R                         *
 18 APR 80 1200  .       C.R                                        *
 20 APR 80 1200  .      C   R                                       *
 22 APR 80 1200  .       C                                          *
 24 APR 80 1200  .      C                                           *
 26 APR 80 1200  .     C                                            *
 28 APR 80 1200  .    C                                             *
 30 APR 80 1200  .    C                                             *
  2 MAY 80 1200  .   C                                              *
  4 MAY 80 1200  .  C                                               *
  6 MAY 80 1200  .  C                                               *
  8 MAY 80 1200  .  C                                               *
 10 MAY 80 1200  . C                                                *
 12 MAY 80 1200  . C                                                *
 14 MAY 80 1200  . C                                                *
 16 MAY 80 1200  . C                                                *
 18 MAY 80 1200  .C                                                 *
 20 MAY 80 1200  .C                                                 *
 22 MAY 80 1200  .C                                                 *
 24 MAY 80 1200  .C                                                 *
 26 MAY 80 1200  .C                                                 *
 28 MAY 80 1200  .C                                                 *
 30 MAY 80 1200  .C                                                 *
  1 JUN 80 1200  .C                                                 *
  3 JUN 80 1200  .C                                                 *
  5 JUN 80 1200  .C                                                 *
  7 JUN 80 1200  .C                                                 *
  9 JUN 80 1200  .C                                                 *
 11 JUN 80 1200  .C                                                 *
 13 JUN 80 1200  .C                                                 *
 15 JUN 80 1200  .C                                                 *
 17 JUN 80 1200  .CR                                                *
 19 JUN 80 1200  .CR                                                *
 21 JUN 80 1200  .C                                                 *
 23 JUN 80 1200  .C                                                 *
 25 JUN 80 1200  .C                                                 *
  7 JUN 80 1200  .C                                                 *
 29 JUN 80 1200  .C                                                 *
  1 JUL 80 1200  .C                                                 *
  3 JUL 80 1200  .C                                                 *
  5 JUL 80 1200  .C                                                 *
  7 JUL 80 1200  .C                                                 *
  9 JUL 80 1200  .C                                                 *
 11 JUL 80 1200  .C                                                 *
 13 JUL 80 1200  .C                                                 *
 15 JUL 80 1200  .C                                                 *
 17 JUL 80 1200  .C                                                 *
 19 JUL 80 1200  .C                                                 *
 21 JUL 80 1200  .C                                                 *
 23 JUL 80 1200  .C                                                 *
 25 JUL 80 1200  .C                                                 *
 27 JUL 80 1200  .C                                                 *
 29 JUL 80 1200  .C                                                 *
 31 JUL 80 1200  .C                                                 *
  2 AUG 80 1200  .C                                                 *
  4 AUG 80 1200  .C                                                 *
  6 AUG 80 1200  .CR                                                *
  8 AUG 80 1200  .  C R                                             *
```

16	AUG	80	1200	C
18	AUG	80	1200	C
20	AUG	80	1200	C
22	AUG	80	1200	C
24	AUG	80	1200	C
26	AUG	80	1200	C
28	AUG	80	1200	R C
30	AUG	80	1200	C
1	SEP	80	1200	C
3	SEP	80	1200	C
5	SEP	80	1200	C
7	SEP	80	1200	C
9	SEP	80	1200	C
11	SEP	80	1200	C
13	SEP	80	1200	C
15	SEP	80	1200	C
17	SEP	80	1200	C
19	SEP	80	1200	C
21	SEP	80	1200	C
23	SEP	80	1200	C
25	SEP	80	1200	C
27	SEP	80	1200	RC
29	SEP	80	1200	C
1	OCT	80	1200	C
3	OCT	80	1200	RC
5	OCT	80	1200	C
7	OCT	80	1200	C
9	OCT	80	1200	C
11	OCT	80	1200	C
13	OCT	80	1200	CR
15	OCT	80	1200	C
17	OCT	80	1200	C
19	OCT	80	1200	CR
21	OCT	80	1200	C
23	OCT	80	1200	C
25	OCT	80	1200	C
27	OCT	80	1200	C
29	OCT	80	1200	C
31	OCT	80	1200	CR
2	NOV	80	1200	C
4	NOV	80	1200	C
6	NOV	80	1200	C
8	NOV	80	1200	C
10	NOV	80	1200	C
12	NOV	80	1200	C
14	NOV	80	1200	C
16	NOV	80	1200	RC
18	NOV	80	1200	C
20	NOV	80	1200	C
22	NOV	80	1200	C
24	NOV	80	1200	C
26	NOV	80	1200	C
28	NOV	80	1200	C
30	NOV	80	1200	C
2	DEC	80	1200	C
4	DEC	80	1200	C
6	DEC	80	1200	C

8	DEC	80	1200	C
10	DEC	80	1200	C
12	DEC	80	1200	C
14	DEC	80	1200	CR
16	DEC	80	1200	CR
18	DEC	80	1200	CR
20	DEC	80	1200	C
22	DEC	80	1200	C
24	DEC	80	1200	C
26	DEC	80	1200	C
28	DEC	80	1200	C
30	DEC	80	1200	C

```
12 APR 88 1200    C
14 APR 88 1200    C
16 APR 88 1200    C
18 APR 88 1200    C
20 APR 88 1200    C
22 APR 88 1200   CR
24 APR 88 1200   CR
26 APR 88 1200    C
28 APR 88 1200    C
30 APR 88 1200    C
 2 MAY 88 1200    C
 4 MAY 88 1200    C
 6 MAY 88 1200    C
 8 MAY 88 1200    C
10 MAY 88 1200    C
12 MAY 88 1200    C
14 MAY 88 1200    C
16 MAY 88 1200    C
18 MAY 88 1200    C
20 MAY 88 1200    C
22 MAY 88 1200   CR
24 MAY 88 1200   CR
26 MAY 88 1200    C
28 MAY 88 1200    C
30 MAY 88 1200    C
 1 JUN 88 1200    C
 3 JUN 88 1200    C
 5 JUN 88 1200    C
 7 JUN 88 1200    C
 9 JUN 88 1200    C
11 JUN 88 1200    C
13 JUN 88 1200    C
15 JUN 88 1200   CR
17 JUN 88 1200   CR
19 JUN 88 1200    C
21 JUN 88 1200    C
23 JUN 88 1200    C
25 JUN 88 1200    C
27 JUN 88 1200    C
29 JUN 88 1200   CR
 1 JUL 88 1200    C
 3 JUL 88 1200    C
 5 JUL 88 1200    C
 7 JUL 88 1200    C
 9 JUL 88 1200    C
11 JUL 88 1200    C
13 JUL 88 1200    C
15 JUL 88 1200    C
17 JUL 88 1200    C
19 JUL 88 1200    C
21 JUL 88 1200    C
23 JUL 88 1200    C
25 JUL 88 1200    C
27 JUL 88 1200    C
29 JUL 88 1200    C
31 JUL 88 1200    C
 2 AUG 88 1200    C
 4 AUG 88 1200    C
 6 AUG 88 1200    C
 8 AUG 88 1200    C
```

```
10 AUG 88 1200    C
12 AUG 88 1200    C
14 AUG 88 1200   RE
16 AUG 88 1200    C
18 AUG 88 1200    C
20 AUG 88 1200    C
22 AUG 88 1200    C
24 AUG 88 1200    C
26 AUG 88 1200    C
28 AUG 88 1200    C
30 AUG 88 1200    C
 1 SEP 88 1200    C
 3 SEP 88 1200    C
 5 SEP 88 1200    C
 7 SEP 88 1200    C
 9 SEP 88 1200     C
11 SEP 88 1200     C
13 SEP 88 1200     C
15 SEP 88 1200    CR
17 SEP 88 1200     C
19 SEP 88 1200     C
21 SEP 88 1200     C
23 SEP 88 1200    CR
25 SEP 88 1200      C
27 SEP 88 1200       C  R
29 SEP 88 1200        C  R
 1 OCT 88 1200          C  R
 3 OCT 88 1200          CR
 5 OCT 88 1200         C  R
 7 OCT 88 1200         CR
 9 OCT 88 1200        CR
11 OCT 88 1200        CR
13 OCT 88 1200        CR
15 OCT 88 1200       CR
17 OCT 88 1200       CR
19 OCT 88 1200       CR
21 OCT 88 1200       CR
23 OCT 88 1200       CR
25 OCT 88 1200       C
27 OCT 88 1200       C
29 OCT 88 1200       CR
31 OCT 88 1200      CR
 2 NOV 88 1200      CR
 4 NOV 88 1200      C
 6 NOV 88 1200      C
 8 NOV 88 1200      C
10 NOV 88 1200      C
12 NOV 88 1200      C
14 NOV 88 1200     CR
16 NOV 88 1200     C
18 NOV 88 1200     C
20 NOV 88 1200     C
22 NOV 88 1200     C
24 NOV 88 1200     C
26 NOV 88 1200     C
28 NOV 88 1200    RC
30 NOV 88 1200     C
 2 DEC 88 1200     C
 4 DEC 88 1200     C
 6 DEC 88 1200     C
```

8	DEC	68	1200	C
10	DEC	68	1200	C
12	DEC	68	1200	C
14	DEC	68	1200	C
16	DEC	68	1200	C
18	DEC	68	1200	C
20	DEC	68	1200	C
22	DEC	68	1200	C
24	DEC	68	1200	RC
26	DEC	68	1200	RC
28	DEC	68	1200	C
30	DEC	68	1200	C
1	JAN	69	1200	C
3	JAN	69	1200	CR
5	JAN	69	1200	CR
7	JAN	69	1200	CR
9	JAN	69	1200	CR
11	JAN	69	1200	CR
13	JAN	69	1200	C
15	JAN	69	1200	C
17	JAN	69	1200	C
19	JAN	69	1200	RC
21	JAN	69	1200	C
23	JAN	69	1200	RC
25	JAN	69	1200	C
27	JAN	69	1200	C
29	JAN	69	1200	C
31	JAN	69	1200	C
2	FEB	69	1200	CR
4	FEB	69	1200	CR
6	FEB	69	1200	CR
8	FEB	69	1200	C
10	FEB	69	1200	CR
12	FEB	69	1200	RC
14	FEB	69	1200	C
16	FEB	69	1200	C
18	FEB	69	1200	C
20	FEB	69	1200	C
22	FEB	69	1200	C
24	FEB	69	1200	C
26	FEB	69	1200	C
28	FEB	69	1200	C
2	MAR	69	1200	C
4	MAR	69	1200	C
6	MAR	69	1200	CR
8	MAR	69	1200	CR
10	MAR	69	1200	C
12	MAR	69	1200	C
14	MAR	69	1200	C
16	MAR	69	1200	C
18	MAR	69	1200	C
20	MAR	69	1200	C
22	MAR	69	1200	C
24	MAR	69	1200	C
26	MAR	69	1200	C
28	MAR	69	1200	C
30	MAR	69	1200	CR
1	APR	69	1200	C
3	APR	69	1200	CR
5	APR	69	1200	C
7	APR	69	1200	C
9	APR	69	1200	C
11	APR	69	1200	RC
13	APR	69	1200	CR
15	APR	69	1200	C R
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19	APR	69	1200	C R
21	APR	69	1200	C R
23	APR	69	1200	C R
25	APR	69	1200	RC
27	APR	69	1200	R C
29	APR	69	1200	R C
1	MAY	69	1200	C
3	MAY	69	1200	RC
5	MAY	69	1200	RC
7	MAY	69	1200	CR
9	MAY	69	1200	C
11	MAY	69	1200	C
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4	JUN	69	1200	CR
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18	JUN	69	1200	C
20	JUN	69	1200	RC
22	JUN	69	1200	C
24	JUN	69	1200	C
26	JUN	69	1200	C
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26	JUL	69	1200	C
28	JUL	69	1200	C
30	JUL	69	1200	C
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3	AUG	69	1200	C

```
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 7 AUG 69 1200     CR
 9 AUG 69 1200     RC
11 AUG 69 1200     R C
13 AUG 69 1200     RC
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17 AUG 69 1200      C
19 AUG 69 1200      C
21 AUG 69 1200      C
23 AUG 69 1200     C
25 AUG 69 1200     C
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29 AUG 69 1200    RC
31 AUG 69 1200    C
 2 SEP 69 1200    C
 4 SEP 69 1200    C
 6 SEP 69 1200    C
 8 SEP 69 1200     C
10 SEP 69 1200     CR
12 SEP 69 1200      C
14 SEP 69 1200      C
16 SEP 69 1200      C
18 SEP 69 1200      C
20 SEP 69 1200      C
22 SEP 69 1200      C
24 SEP 69 1200      C
26 SEP 69 1200      C
28 SEP 69 1200      C
30 SEP 69 1200      C
 2 OCT 69 1200      C
 4 OCT 69 1200       C
 6 OCT 69 1200        C
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11 NOV 69 1200    RC
13 NOV 69 1200    RC
15 NOV 69 1200    RC
17 NOV 69 1200    RC
19 NOV 69 1200    RC
21 NOV 69 1200    RC
23 NOV 69 1200    RC
25 NOV 69 1200    RC
27 NOV 69 1200    RC
29 NOV 69 1200    RC
 1 DEC 69 1200    RC
```

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 5 DEC 69 1200    C
 7 DEC 69 1200    C
 9 DEC 69 1200    C
11 DEC 69 1200    C
13 DEC 69 1200    C
15 DEC 69 1200    C
17 DEC 69 1200    C
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21 DEC 69 1200    C
23 DEC 69 1200    C
25 DEC 69 1200   RC
27 DEC 69 1200   RC
29 DEC 69 1200   RC
31 DEC 69 1200   RC
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 4 JAN 70 1200   RC
 6 JAN 70 1200   RC
 8 JAN 70 1200   RC
10 JAN 70 1200   RC
12 JAN 70 1200   RC
14 JAN 70 1200   C
16 JAN 70 1200   C
18 JAN 70 1200   C
20 JAN 70 1200   C
22 JAN 70 1200   C
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26 JAN 70 1200   C
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30 JAN 70 1200   C
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 3 FEB 70 1200   C
 5 FEB 70 1200   C
 7 FEB 70 1200   C
 9 FEB 70 1200   C
11 FEB 70 1200   C
13 FEB 70 1200   C
15 FEB 70 1200   C
17 FEB 70 1200   C
19 FEB 70 1200   C
21 FEB 70 1200   C
23 FEB 70 1200   C
25 FEB 70 1200   C
27 FEB 70 1200   C
 1 MAR 70 1200   C
 3 MAR 70 1200   C
 5 MAR 70 1200   C
 7 MAR 70 1200   C
 9 MAR 70 1200   C
11 MAR 70 1200   C
13 MAR 70 1200   C
15 MAR 70 1200   C
17 MAR 70 1200   C
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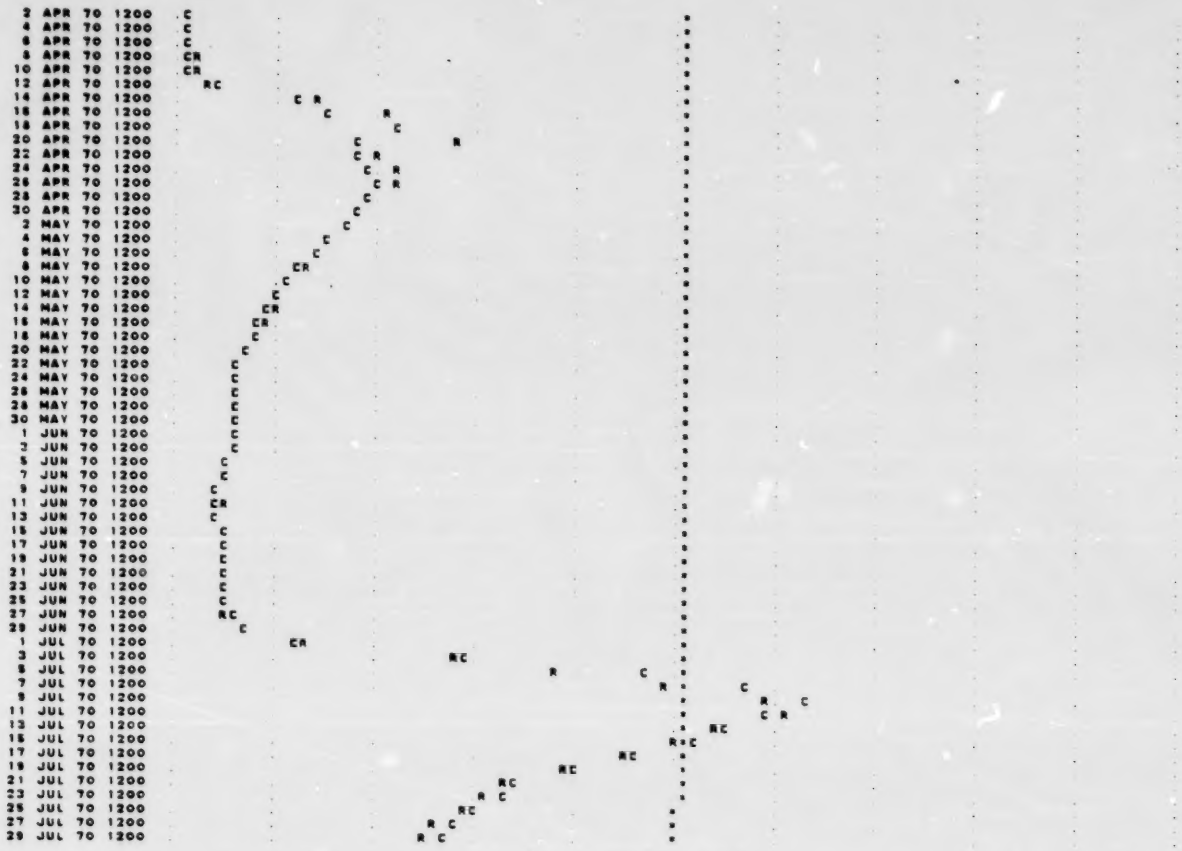
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4 MAY 70 1200
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1 JUN 70 1200
3 JUN 70 1200
5 JUN 70 1200
7 JUN 70 1200
9 JUN 70 1200
11 JUN 70 1200
13 JUN 70 1200
15 JUN 70 1200
17 JUN 70 1200
19 JUN 70 1200
21 JUN 70 1200
23 JUN 70 1200
25 JUN 70 1200
27 JUN 70 1200
29 JUN 70 1200
1 JUL 70 1200
3 JUL 70 1200
5 JUL 70 1200
7 JUL 70 1200
9 JUL 70 1200
11 JUL 70 1200
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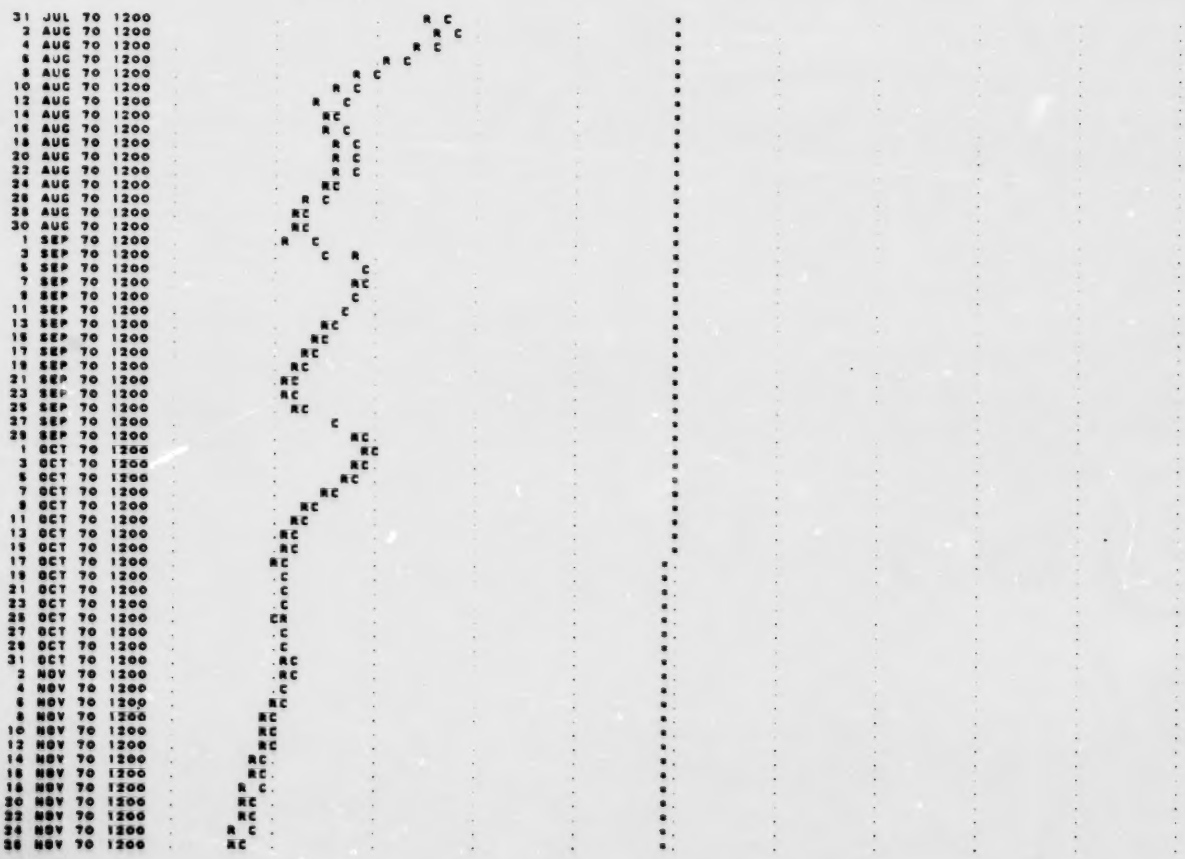
29 JUL 70 1200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6 AUG 70 1200
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18 AUG 70 1200
20 AUG 70 1200
22 AUG 70 1200
24 AUG 70 1200
26 AUG 70 1200
28 AUG 70 1200
30 AUG 70 1200
1 SEP 70 1200
3 SEP 70 1200
5 SEP 70 1200
7 SEP 70 1200
9 SEP 70 1200
11 SEP 70 1200
13 SEP 70 1200
15 SEP 70 1200
17 SEP 70 1200
19 SEP 70 1200
21 SEP 70 1200
23 SEP 70 1200
25 SEP 70 1200
27 SEP 70 1200
29 SEP 70 1200
1 OCT 70 1200
3 OCT 70 1200
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7 OCT 70 1200
9 OCT 70 1200
11 OCT 70 1200
13 OCT 70 1200
15 OCT 70 1200
17 OCT 70 1200
19 OCT 70 1200
21 OCT 70 1200
23 OCT 70 1200
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29 OCT 70 1200
31 OCT 70 1200
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4 NOV 70 1200
6 NOV 70 1200
8 NOV 70 1200
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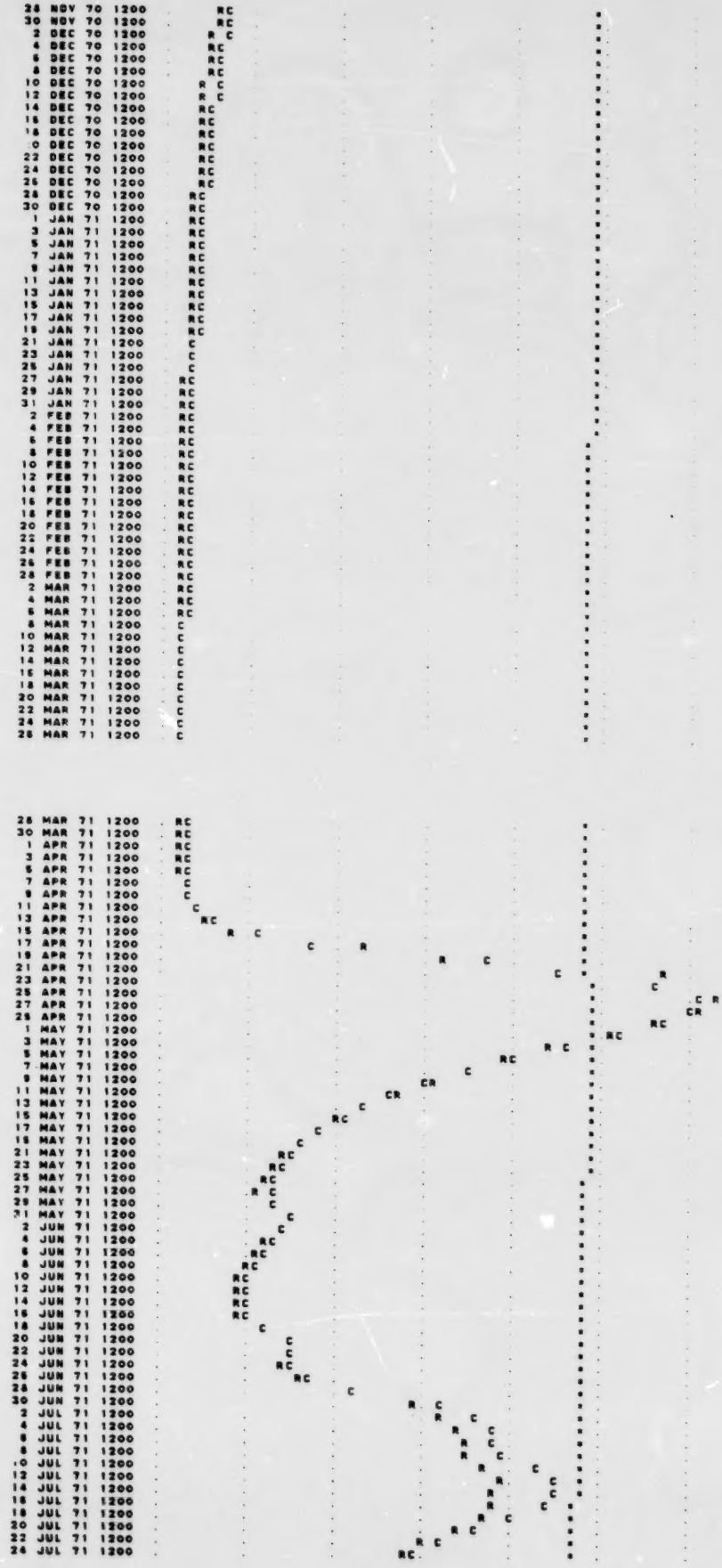
26 NOV 70 1200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3 JAN 71 1200
5 JAN 71 1200
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9 JAN 71 1200
11 JAN 71 1200
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15 JAN 71 1200
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14 JUL 71 1200
16 JUL 71 1200
18 JUL 71 1200
20 JUL 71 1200
22 JUL 71 1200
24 JUL 71 1200

26 JUL 71 1200	RC
28 JUL 71 1200	RC
30 JUL 71 1200	RC
1 AUG 71 1200	RC
3 AUG 71 1200	RC
5 AUG 71 1200	RC
7 AUG 71 1200	RC
9 AUG 71 1200	RC
11 AUG 71 120.	RC
13 AUG 71 1200	RC
15 AUG 71 1200	RC
17 AUG 71 1200	RC
19 AUG 71 1200	RC
21 AUG 71 1200	RC
23 AUG 71 1200	RC
25 AUG 71 1200	RC
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29 AUG 71 1200	RC
31 AUG 71 1200	RC
2 SEP 71 1200	RC
4 SEP 71 1200	RC
6 SEP 71 1200	RC
8 SEP 71 1200	RC
10 SEP 71 1200	C
12 SEP 71 1200	RC
14 SEP 71 1200	RC
16 SEP 71 1200	RC
18 SEP 71 1200	RC
20 SEP 71 1200	C
22 SEP 71 1200	C
24 SEP 71 1200	RC
26 SEP 71 1200	RC
28 SEP 71 1200	RC
30 SEP 71 1200	RC
2 OCT 71 1200	RC
4 OCT 71 1200	RC
6 OCT 71 1200	RC
8 OCT 71 1200	C
10 OCT 71 1200	C
12 OCT 71 1200	C
14 OCT 71 1200	C
16 OCT 71 1200	C
18 OCT 71 1200	C
20 OCT 71 1200	C
22 OCT 71 1200	RC
24 OCT 71 1200	RC
26 OCT 71 1200	RC
28 OCT 71 1200	RC
30 OCT 71 1200	C
1 NOV 71 1200	C
3 NOV 71 1200	C
5 NOV 71 1200	C
7 NOV 71 1200	C
9 NOV 71 1200	C
11 NOV 71 1200	C
13 NOV 71 1200	C
15 NOV 71 1200	C
17 NOV 71 1200	C
19 NOV 71 1200	C
21 NOV 71 1200	C
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7 DEC 71 1200	C
9 DEC 71 1200	C
11 DEC 71 1200	RC
13 DEC 71 1200	RC
15 DEC 71 1200	RC
17 DEC 71 1200	RC
19 DEC 71 1200	RC
21 DEC 71 1200	RC
23 DEC 71 1200	RC
25 DEC 71 1200	RC
27 DEC 71 1200	RC
29 DEC 71 1200	RC
31 DEC 71 1200	RC

```
                                    PLOT      STATION NAME                                    STATION
                                  CHARACTER                                                  NUMBER CONTROL

                                      C-CALC. BEAVER RIVER FLOW AT COLD LAKE                  726.0    0
                                      R-BEAVER R. AT COLD LAKE 06AD005                         52.6    0
FLOW CFS          0       1500.      3000.      4500.      6000.      7500.      9000.     10500.     12000.     13500.     15000.
                                      *-DUMMY RES  (DIFF) AT BEAVER RIVER AT COLD LA          726.2    E
ELEV FT.         -5        -4         -3         -2         -1         -0          1          2          3          4          5
 1 JAN 72 1200   .RC                                                  .
 3 JAN 72 1200   .RC                                                  .
 5 JAN 72 1200   .RC                                                  .
 7 JAN 72 1200   .RC                                                  .
 9 JAN 72 1200   .RC                                                  .
11 JAN 72 1200   .RC                                                  .
13 JAN 72 1200   .RC                                                  .
15 JAN 72 1200   .RC                                                  .
17 JAN 72 1200   .RC                                                  .
19 JAN 72 1200   .RC                                                  .
21 JAN 72 1200   .RC                                                  .
23 JAN 72 1200   .RC                                                  .
25 JAN 72 1200   .RC                                                  .
27 JAN 72 1200   .RC                                                  .
29 JAN 72 1200   .C                                                   .
31 JAN 72 1200   .C                                                   .
 2 FEB 72 1200   .C                                                   .
 4 FEB 72 1200   .C                                                   .
 6 FEB 72 1200   .C                                                   .
 8 FEB 72 1200   .C                                                   .
10 FEB 72 1200   .C                                                   .
12 FEB 72 1200   .C                                                   .
14 FEB 72 1200   .C                                                   .
16 FEB 72 1200   .C                                                   .
18 FEB 72 1200   .C                                                   .
20 FEB 72 1200   .C                                                   .
22 FEB 72 1200   .C                                                   .
24 FEB 72 1200   .C                                                   .
26 FEB 72 1200   .C                                                   .
28 FEB 72 1200   .C                                                   .
 1 MAR 72 1200   .C                                                   .
 3 MAR 72 1200   .C                                                   .
 5 MAR 72 1200   .C                                                   .
 7 MAR 72 1200   .C                                                   .
 9 MAR 72 1200   .C                                                   .
11 MAR 72 1200   .C                                                   .
13 MAR 72 1200   .C                                                   .
15 MAR 72 1200   .C                                                   .
17 MAR 72 1200   .C                                                   .
19 MAR 72 1200   .C                                                   .
21 MAR 72 1200   .C                                                   .
23 MAR 72 1200   .C                                                   .
25 MAR 72 1200   .C                                                   .
27 MAR 72 1200   .C                                                   .
29 MAR 72 1200    .C                                                  .
31 MAR 72 1200    .C                                                  .
 2 APR 72 1200    .C                                                  .
 4 APR 72 1200    .C                                                  .
 6 APR 72 1200    .CR                                                 .
 8 APR 72 1200    .CR                                                 .
10 APR 72 1200    .CR                                                 .
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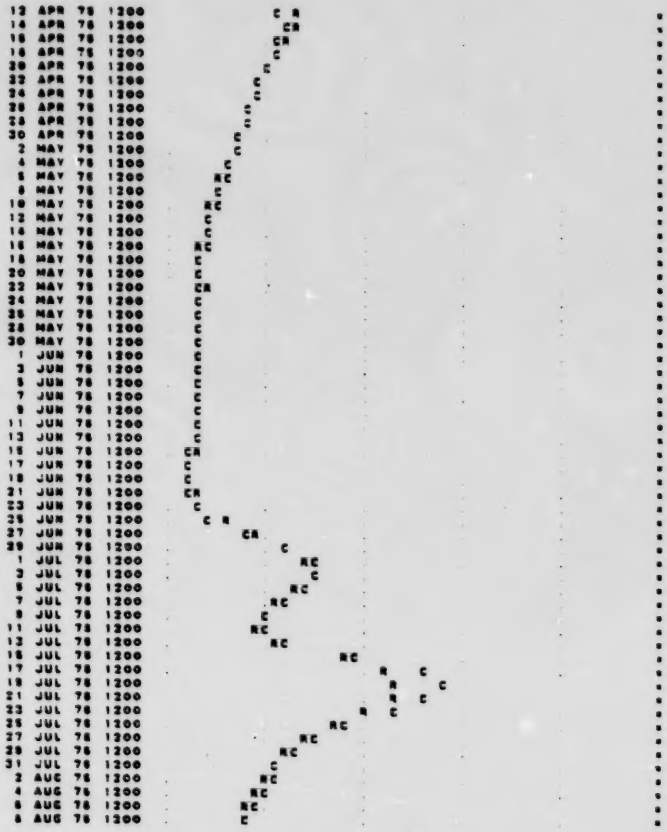
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28 APR 75 1200
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2 MAY 75 1200
4 MAY 75 1200
6 MAY 75 1200
8 MAY 75 1200
10 MAY 75 1200
12 MAY 75 1200
14 MAY 75 1200
16 MAY 75 1200
18 MAY 75 1200
20 MAY 75 1200
22 MAY 75 1200
24 MAY 75 1200
26 MAY 75 1200
28 MAY 75 1200
30 MAY 75 1200
1 JUN 75 1200
3 JUN 75 1200
5 JUN 75 1200
7 JUN 75 1200
9 JUN 75 1200
11 JUN 75 1200
13 JUN 75 1200
15 JUN 75 1200
17 JUN 75 1200
19 JUN 75 1200
21 JUN 75 1200
23 JUN 75 1200
25 JUN 75 1200
27 JUN 75 1200
29 JUN 75 1200
1 JUL 75 1200
3 JUL 75 1200
5 JUL 75 1200
7 JUL 75 1200
9 JUL 75 1200
11 JUL 75 1200
13 JUL 75 1200
15 JUL 75 1200
17 JUL 75 1200
19 JUL 75 1200
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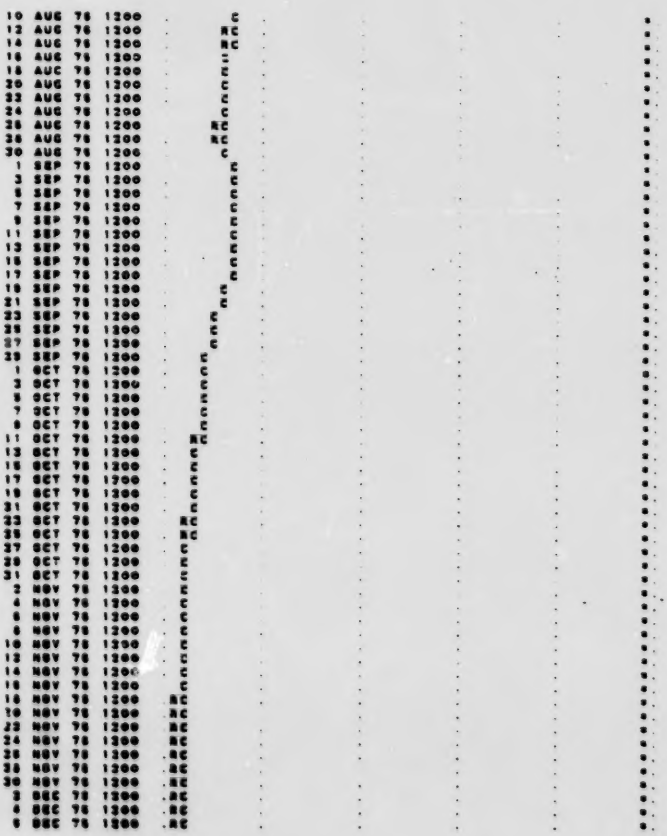
2 AUG 75 1200
4 AUG 75 1200
6 AUG 75 1200
8 AUG 75 1200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28 AUG 75 1200
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3 SEP 75 1200
5 SEP 75 1200
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9 SEP 75 1200
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20 NOV 75 1200
22 NOV 75 1200
24 NOV 75 1200
26 NOV 75 1200
28 NOV 75 1200
30 NOV 75 1200
2 DEC 75 1200
4 DEC 75 1200
6 DEC 75 1200

```
 8 DEC 76 1200   .RC
10 DEC 76 1200   .RC
12 DEC 76 1200   .RC
14 DEC 76 1200   .RC
16 DEC 76 1200   .RC
18 DEC 76 1200   .RC
20 DEC 76 1200   .RC
22 DEC 76 1200   .RC
24 DEC 76 1200   .RC
26 DEC 76 1200   .RC
28 DEC 76 1200   .C
30 DEC 76 1200   .C
 1 JAN 77 1200   .C
 3 JAN 77 1200   .C
 5 JAN 77 1200   .C
 7 JAN 77 1200   .C
 9 JAN 77 1200   .C
11 JAN 77 1200   .C
13 JAN 77 1200   .C
15 JAN 77 1200   .C
17 JAN 77 1200   .C
19 JAN 77 1200   .C
21 JAN 77 1200   .C
23 JAN 77 1200   .C
25 JAN 77 1200   .C
27 JAN 77 1200   .C
29 JAN 77 1200   .C
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 2 FEB 77 1200   .C
 4 FEB 77 1200   .C
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12 FEB 77 1200   .C
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16 FEB 77 1200   .C
18 FEB 77 1200   .C
20 FEB 77 1200   .C
22 FEB 77 1200   .C
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26 FEB 77 1200   .C
28 FEB 77 1200   .C
 2 MAR 77 1200   .C
 4 MAR 77 1200   .C
 6 MAR 77 1200   .C
 8 MAR 77 1200   .C
10 MAR 77 1200   .C
12 MAR 77 1200   .C
14 MAR 77 1200   .C
16 MAR 77 1200   .C
18 MAR 77 1200   .C
20 MAR 77 1200   .C
22 MAR 77 1200   .C
24 MAR 77 1200   .C
26 MAR 77 1200   .C
28 MAR 77 1200   .C
30 MAR 77 1200   .C
 1 APR 77 1200   .C
 3 APR 77 1200   .C
 5 APR 77 1200   .C
```

```
 7 APR 77 1200   .C
 9 APR 77 1200   .RC
11 APR 77 1200   .R C
13 APR 77 1200   .  R   C
15 APR 77 1200   .    R         C
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19 APR 77 1200   .              C R
21 APR 77 1200   .              CR
23 APR 77 1200   .            CR
25 APR 77 1200   .          CR
27 APR 77 1200   .        CR
29 APR 77 1200   .        CR
 1 MAY 77 1200   .      CR
 3 MAY 77 1200   .      CR
 5 MAY 77 1200   .      CR
 7 MAY 77 1200   .      CR
 9 MAY 77 1200   .      C
11 MAY 77 1200   .      C
13 MAY 77 1200   .     CR
15 MAY 77 1200   .      C
17 MAY 77 1200   .        C
19 MAY 77 1200   .            CR
21 MAY 77 1200   .               CR
23 MAY 77 1200   .               C
25 MAY 77 1200   .               CR
27 MAY 77 1200   .               C
29 MAY 77 1200   .               CR
31 MAY 77 1200   .                CR
 2 JUN 77 1200   .                CR
 4 JUN 77 1200   .               CR
 6 JUN 77 1200   .             CR
 8 JUN 77 1200   .           C
10 JUN 77 1200   .         C
12 JUN 77 1200   .       C
14 JUN 77 1200   .       C
16 JUN 77 1200   .     C
18 JUN 77 1200   .    RC
20 JUN 77 1200   .    RC
22 JUN 77 1200   .   RC
24 JUN 77 1200   .   RC
26 JUN 77 1200   .   RC
28 JUN 77 1200   .   C
30 JUN 77 1200   .   C
 2 JUL 77 1200   .  RC
 4 JUL 77 1200   .  RC
 6 JUL 77 1200   .  C
 8 JUL 77 1200   .  C
10 JUL 77 1200   . CR
12 JUL 77 1200   .  C
14 JUL 77 1200   .  C
16 JUL 77 1200   .   C
18 JUL 77 1200   .   C
20 JUL 77 1200   .   C
22 JUL 77 1200   .   C
24 JUL 77 1200   .    C
26 JUL 77 1200   .   RC
28 JUL 77 1200   .    C
30 JUL 77 1200   .   CR
 1 AUG 77 1200   .    C
 3 AUG 77 1200   .   CR
```

5	AUG	77	1200	CR
7	AUG	77	1200	C
9	AUG	77	1200	C
11	AUG	77	1200	C
13	AUG	77	1200	CR
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17	AUG	77	1200	CR
19	AUG	77	1200	C
21	AUG	77	1200	C
23	AUG	77	1200	C
25	AUG	77	1200	C
27	AUG	77	1200	C
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10	SEP	77	1200	C
12	SEP	77	1200	C
14	SEP	77	1200	C
16	SEP	77	1200	C
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20	SEP	77	1200	CR
22	SEP	77	1200	CR
24	SEP	77	1200	CR
26	SEP	77	1200	CR
28	SEP	77	1200	CR
30	SEP	77	1200	C
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10	OCT	77	1200	CR
12	OCT	77	1200	CR
14	OCT	77	1200	CR
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18	OCT	77	1200	C
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22	OCT	77	1200	CR
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23	NOV	77	1200	RC
25	NOV	77	1200	RC
27	NOV	77	1200	RC
29	NOV	77	1200	RC
1	DEC	77	1200	RC
3	DEC	77	1200	RC
5	DEC	77	1200	RC
7	DEC	77	1200	RC
9	DEC	77	1200	RC
11	DEC	77	1200	RC
13	DEC	77	1200	RC
15	DEC	77	1200	RC
17	DEC	77	1200	RC
19	DEC	77	1200	RC
21	DEC	77	1200	RC
23	DEC	77	1200	RC
25	DEC	77	1200	RC
27	DEC	77	1200	RC
29	DEC	77	1200	RC
31	DEC	77	1200	RC
2	JAN	78	1200	RC
4	JAN	78	1200	RC
6	JAN	78	1200	RC
8	JAN	78	1200	RC
10	JAN	78	1200	RC
12	JAN	78	1200	C
14	JAN	78	1200	C
16	JAN	78	1200	C
18	JAN	78	1200	C
20	JAN	78	1200	C
22	JAN	78	1200	C
24	JAN	78	1200	C
26	JAN	78	1200	C
28	JAN	78	1200	C
30	JAN	78	1200	C
1	FEB	78	1200	C
3	FEB	78	1200	C
5	FEB	78	1200	C
7	FEB	78	1200	C
9	FEB	78	1200	C
11	FEB	78	1200	C
13	FEB	78	1200	C
15	FEB	78	1200	C
17	FEB	78	1200	C
19	FEB	78	1200	C
21	FEB	78	1200	C
23	FEB	78	1200	C
25	FEB	78	1200	C
27	FEB	78	1200	C
1	MAR	78	1200	C
3	MAR	78	1200	C
5	MAR	78	1200	C
7	MAR	78	1200	C
9	MAR	78	1200	C
11	MAR	78	1200	C
13	MAR	78	1200	C
15	MAR	78	1200	C
17	MAR	78	1200	C
19	MAR	78	1200	C
21	MAR	78	1200	C
23	MAR	78	1200	C
25	MAR	78	1200	C
27	MAR	78	1200	C
29	MAR	78	1200	C
31	MAR	78	1200	C

```
 3 APR 78 1200      RC
 4 APR 78 1200       RC
 5 APR 78 1200       RC
 6 APR 78 1200         CR
10 APR 78 1200         CR
12 APR 78 1200           C
14 APR 78 1200            C
16 APR 78 1200          RC
18 APR 78 1200        R C
20 APR 78 1200         RC
22 APR 78 1200          C
24 APR 78 1200         CR
26 APR 78 1200          CR
28 APR 78 1200           RC
30 APR 78 1200            C
 2 MAY 78 1200           RC
 4 MAY 78 1200           RC
 6 MAY 78 1200           RC
 8 MAY 78 1200          R C
10 MAY 78 1200          RC
12 MAY 78 1200          RC
14 MAY 78 1200         RC
16 MAY 78 1200         RC
18 MAY 78 1200        RC
20 MAY 78 1200        RC
22 MAY 78 1200       RC
24 MAY 78 1200       RC
26 MAY 78 1200       RC
28 MAY 78 1200        R C
30 MAY 78 1200            R C
 1 JUN 78 1200                      RC
 3 JUN 78 1200                          R    C
 5 JUN 78 1200                                CR
 7 JUN 78 1200                          C    R
 9 JUN 78 1200                      CR
11 JUN 78 1200                  CR
13 JUN 78 1200              CR
15 JUN 78 1200                C
17 JUN 78 1200                 C
19 JUN 78 1200                  C
21 JUN 78 1200                 RC
23 JUN 78 1200               RC
25 JUN 78 1200              RC
27 JUN 78 1200             RC
29 JUN 78 1200              C
 1 JUL 78 1200           C
 3 JUL 78 1200         RC
 5 JUL 78 1200         C
 7 JUL 78 1200       C
 9 JUL 78 1200      RC
11 JUL 78 1200      C
13 JUL 78 1200     RC
15 JUL 78 1200      C
17 JUL 78 1200      C
19 JUL 78 1200      C
21 JUL 78 1200    C
23 JUL 78 1200    C
25 JUL 78 1200   RC
27 JUL 78 1200   C
29 JUL 78 1200   C

31 JUL 78 1200   C
 2 AUG 78 1200   C
 4 AUG 78 1200   C
 6 AUG 78 1200   C
 8 AUG 78 1200  C
10 AUG 78 1200  C
12 AUG 78 1200  C
14 AUG 78 1200  C
16 AUG 78 1200  C
18 AUG 78 1200  C
20 AUG 78 1200  C
22 AUG 78 1200  C
24 AUG 78 1200  C
26 AUG 78 1200  C
28 AUG 78 1200  C
30 AUG 78 1200  C
 1 SEP 78 1200  C
 3 SEP 78 1200  C
 5 SEP 78 1200  C
 7 SEP 78 1200  C
 9 SEP 78 1200  C
11 SEP 78 1200   CR
13 SEP 78 1200     CR
15 SEP 78 1200      RC
17 SEP 78 1200        C
19 SEP 78 1200         CR
21 SEP 78 1200           C
23 SEP 78 1200            C
25 SEP 78 1200           CR
27 SEP 78 1200          CR
29 SEP 78 1200         CR
 1 OCT 78 1200          C
 3 OCT 78 1200         C
 5 OCT 78 1200        C
 7 OCT 78 1200       CR
 9 OCT 78 1200       C
11 OCT 78 1200      C
13 OCT 78 1200     C
15 OCT 78 1200     C
17 OCT 78 1200    C
19 OCT 78 1200    C
21 OCT 78 1200   CR
23 OCT 78 1200   C
25 OCT 78 1200   C
27 OCT 78 1200   C
29 OCT 78 1200  CR
31 OCT 78 1200  C
 2 NOV 78 1200  C
 4 NOV 78 1200  C
 6 NOV 78 1200  C
 8 NOV 78 1200  C
10 NOV 78 1200  RC
12 NOV 78 1200  C
14 NOV 78 1200  C
16 NOV 78 1200  C
18 NOV 78 1200  RC
20 NOV 78 1200  RC
22 NOV 78 1200 .R C
24 NOV 78 1200 .R C
26 NOV 78 1200 .R C
```

```
28 NOV 78 1200   R C
30 NOV 78 1200   R C
 2 DEC 78 1200   R C
 4 DEC 78 1200   R C
 6 DEC 78 1200   R C
 8 DEC 78 1200    RC
10 DEC 78 1200    RC
12 DEC 78 1200    RC
14 DEC 78 1200    RC
16 DEC 78 1200     C
18 DEC 78 1200     C
20 DEC 78 1200     C
22 DEC 78 1200     C
24 DEC 78 1200     C
26 DEC 78 1200     C
28 DEC 78 1200     C
30 DEC 78 1200     C
 1 JAN 79 1200     C
 3 JAN 79 1200     C
 5 JAN 79 1200     C
 7 JAN 79 1200     C
 9 JAN 79 1200    RC
11 JAN 79 1200    RC
13 JAN 79 1200    RC
15 JAN 79 1200    RC
17 JAN 79 1200    RC
19 JAN 79 1200    RC
21 JAN 79 1200    RC
23 JAN 79 1200    RC
25 JAN 79 1200    RC
27 JAN 79 1200    RC
29 JAN 79 1200    RC
31 JAN 79 1200    RC
 2 FEB 79 1200    RC
 4 FEB 79 1200    RC
 6 FEB 79 1200    RC
 8 FEB 79 1200    RC
10 FEB 79 1200    RC
12 FEB 79 1200     C
14 FEB 79 1200     C
16 FEB 79 1200     C
18 FEB 79 1200     C
20 FEB 79 1200     C
22 FEB 79 1200     C
24 FEB 79 1200     C
26 FEB 79 1200     C
28 FEB 79 1200     C
 2 MAR 79 1200     C
 4 MAR 79 1200     C
 6 MAR 79 1200     C
 8 MAR 79 1200     C
10 MAR 79 1200     C
12 MAR 79 1200     C
14 MAR 79 1200     C
16 MAR 79 1200    CR
18 MAR 79 1200     C
20 MAR 79 1200     C
22 MAR 79 1200     C
24 MAR 79 1200      C
26 MAR 79 1200       CR
```

```
28 MAR 79 1200      C
30 MAR 79 1200     RC
 1 APR 79 1200     C
 3 APR 79 1200     C
 5 APR 79 1200     C
 7 APR 79 1200     C
 9 APR 79 1200     C
11 APR 79 1200     C
13 APR 79 1200      C
15 APR 79 1200       C
17 APR 79 1200       C
19 APR 79 1200       C R
21 APR 79 1200                C   R
23 APR 79 1200                    C R
25 APR 79 1200                          R   C
27 APR 79 1200                          C       R
29 APR 79 1200                          C R
 1 MAY 79 1200                        C   R
 3 MAY 79 1200                          C   R
 5 MAY 79 1200                          C   R
 7 MAY 79 1200                        C   R
 9 MAY 79 1200                      C   R
11 MAY 79 1200                    C R
13 MAY 79 1200                  C R
15 MAY 79 1200                C R
17 MAY 79 1200                CR
19 MAY 79 1200                 CR
21 MAY 79 1200                  CR
23 MAY 79 1200                  C R
25 MAY 79 1200                  C R
27 MAY 79 1200                 C R
29 MAY 79 1200                 C
31 MAY 79 1200               C
 2 JUN 79 1200             C
 4 JUN 79 1200            RC
 6 JUN 79 1200             C
 8 JUN 79 1200               C
10 JUN 79 1200                 C
12 JUN 79 1200                  C
14 JUN 79 1200                  C
16 JUN 79 1200                  C
18 JUN 79 1200                   C
20 JUN 79 1200                  C
22 JUN 79 1200                 C
24 JUN 79 1200               C
26 JUN 79 1200             RC
28 JUN 79 1200            RC
30 JUN 79 1200           RC
 2 JUL 79 1200          RC
 4 JUL 79 1200         RC
 6 JUL 79 1200         C
 8 JUL 79 1200       RC
 9 JUL 79 1200       C
12 JUL 79 1200      RC
14 JUL 79 1200      C
16 JUL 79 1200        C
18 JUL 79 1200         RC
20 JUL 79 1200         C
22 JUL 79 1200          C
24 JUL 79 1200         C
```

26	JUL	79	1200	C
28	JUL	79	1200	C
30	JUL	79	1200	RC
1	AUG	79	1200	C
3	AUG	79	1200	C
5	AUG	79	1200	C
7	AUG	79	1200	C
9	AUG	79	1200	C
11	AUG	79	1200	RC
13	AUG	79	1200	RC
15	AUG	79	1200	C
17	AUG	79	1200	C
19	AUG	79	1200	C
21	AUG	79	1200	C
23	AUG	79	1200	RC
25	AUG	79	1200	C
27	AUG	79	1200	C
29	AUG	79	1200	C
31	AUG	79	1200	C
2	SEP	79	1200	C
4	SEP	79	1200	C
6	SEP	79	1200	C
8	SEP	79	1200	C
10	SEP	79	1200	CR
12	SEP	79	1200	C
14	SEP	79	1200	C
16	SEP	79	1200	CR
18	SEP	79	1200	C
20	SEP	79	1200	C
22	SEP	79	1200	C
24	SEP	79	1200	C
26	SEP	79	1200	C
28	SEP	79	1200	C
30	SEP	79	1200	C
2	OCT	79	1200	C
4	OCT	79	1200	C
6	OCT	79	1200	C
8	OCT	79	1200	C
10	OCT	79	1200	RC
12	OCT	79	1200	C
14	OCT	79	1200	C
16	OCT	79	1200	C
18	OCT	79	1200	C
20	OCT	79	1200	C
22	OCT	79	1200	C
24	OCT	79	1200	C
26	OCT	79	1200	C
28	OCT	79	1200	C
30	OCT	79	1200	CR
1	NOV	79	1200	CR
3	NOV	79	1200	C
5	NOV	79	1200	C
7	NOV	79	1200	C
9	NOV	79	1200	C
11	NOV	79	1200	C
13	NOV	79	1200	C
15	NOV	79	1200	C
17	NOV	79	1200	C
19	NOV	79	1200	C
21	NOV	79	1200	C
23	NOV	79	1200	RC
25	NOV	79	1200	RC
27	NOV	79	1200	RC
29	NOV	79	1200	RC
1	DEC	79	1200	RC
3	DEC	79	1200	RC
5	DEC	79	1200	RC
7	DEC	79	1200	RC
9	DEC	79	1200	RC
11	DEC	79	1200	RC
13	DEC	79	1200	RC
15	DEC	79	1200	RC
17	DEC	79	1200	RC
19	DEC	79	1200	RC
21	DEC	79	1200	RC
23	DEC	79	1200	RC
25	DEC	79	1200	C
27	DEC	79	1200	C
29	DEC	79	1200	C
31	DEC	79	1200	C

```
                                   CAVALIER                                                  NUMBER CONTROL
                                           C-CALC. BEAVER RIVER FLOW AT COLD LAKE                 726.0   0
                                           R-BEAVER R. AT COLD LAKE 06AD006                        52.6   0
FLOW CFS          0.       1500.      3000      4500.     6000.      7500.     9000     10500.    12000.     13500.     15000
                                           *-DUMMY RES  (DIFF) AT BEAVER RIVER AT COLD LA         726.2   I
ELEV FT.         -5          -4         -3.        -2        -1        -0         1.        2          3.         4          5
  1 JAN 80 1200  .C
  3 JAN 80 1200   C
  5 JAN 80 1200  .C
  7 JAN 80 1200   C
  9 JAN 80 1200  .C
 11 JAN 80 1200  .C
 13 JAN 80 1200   C
 15 JAN 80 1200  .C
 17 JAN 80 1200  .C
 19 JAN 80 1200  .C
 21 JAN 80 1200  .C
 23 JAN 80 1200  .C
 25 JAN 80 1200  .C
 27 JAN 80 1200  .C
 29 JAN 80 1200  .C
 31 JAN 80 1200   C
  2 FEB 80 1200  .C
  4 FEB 80 1200   C
  6 FEB 80 1200  .C
  8 FEB 80 1200  .C
 10 FEB 80 1200  .C
 12 FEB 80 1200  .C
 14 FEB 80 1200   C
 16 FEB 80 1200  .C
 18 FEB 80 1200  .C
 20 FEB 80 1200   C
 22 FEB 80 1200   C
 24 FEB 80 1200   C
 26 FEB 80 1200  .C
 28 FEB 80 1200  .C
  1 MAR 80 1200   C
  3 MAR 80 1200  .C
  5 MAR 80 1200  .C
  7 MAR 80 1200  .C
  9 MAR 80 1200  .C
 11 MAR 80 1200  .C
 13 MAR 80 1200  .C
 15 MAR 80 1200  .C
 17 MAR 80 1200  .C
 19 MAR 80 1200  .C
 21 MAR 80 1200  .C
 23 MAR 80 1200  .C
 25 MAR 80 1200   C
 27 MAR 80 1200  .C
 29 MAR 80 1200  .C
 31 MAR 80 1200   C
  2 APR 80 1200  .CR
  4 APR 80 1200   C
  6 APR 80 1200  .C
  8 APR 80 1200  .  CR
 10 APR 80 1200  .       C R

 12 APR 80 1200  .            C .R
 14 APR 80 1200  .               R C
 16 APR 80 1200  .              C                R
 18 APR 80 1200  .             C.R
 20 APR 80 1200  .            C  R
 22 APR 80 1200  .             C.
 24 APR 80 1200  .            C
 26 APR 80 1200  .           C
 28 APR 80 1200  .          C
 30 APR 80 1200  .          C
  2 MAY 80 1200  .         C
  4 MAY 80 1200  .        C
  6 MAY 80 1200  .        C
  8 MAY 80 1200  .        C
 10 MAY 80 1200  .       C
 12 MAY 80 1200  .       C
 14 MAY 80 1200  .       C
 16 MAY 80 1200  .       C
 18 MAY 80 1200  .     C
 20 MAY 80 1200  .     C
 22 MAY 80 1200  .     C
 24 MAY 80 1200  .     C
 26 MAY 80 1200        C
 28 MAY 80 1200        C
 30 MAY 80 1200        C
  1 JUN 80 1200        C
  3 JUN 80 1200        C
  5 JUN 80 1200  .     C
  7 JUN 80 1200  .     C
  9 JUN 80 1200        C
 11 JUN 80 1200  .     C
 13 JUN 80 1200  .     C
 15 JUN 80 1200  .     C
 17 JUN 80 1200  CR
 19 JUN 80 1200  .CR
 21 JUN 80 1200  .C
 23 JUN 80 1200  .C
 25 JUN 80 1200  .C
  ? JUN 80 1200  .C
 29 JUN 80 1200   C
  1 JUL 80 1200   C
  3 JUL 80 1200  .C
  5 JUL 80 1200   C
  7 JUL 80 1200  .C
  9 JUL 80 1200  .C
 11 JUL 80 1200   C
 13 JUL 80 1200  .C
 15 JUL 80 1200  .C
 17 JUL 80 1200  .C
 19 JUL 80 1200  .C
 21 JUL 80 1200  .C
 23 JUL 80 1200  .C
 25 JUL 80 1200  .C
 27 JUL 80 1200  .C
 29 JUL 80 1200  .C
 31 JUL 80 1200  .C
  2 AUG 80 1200  .C
  4 AUG 80 1200  .C
  6 AUG 80 1200  .CR
  8 AUG 80 1200  .    C R
```

14	AUG	80	1200	RC
16	AUG	80	1200	C
18	AUG	80	1200	C
20	AUG	80	1200	C
22	AUG	80	1200	C
24	AUG	80	1200	C
26	AUG	80	1200	C
28	AUG	80	1200	R C
30	AUG	80	1200	C
1	SEP	80	1200	C
3	SEP	80	1200	C
5	SEP	80	1200	C
7	SEP	80	1200	C
9	SEP	80	1200	C
11	SEP	80	1200	C
13	SEP	80	1200	C
15	SEP	80	1200	C
17	SEP	80	1200	C
19	SEP	80	1200	C
21	SEP	80	1200	C
23	SEP	80	1200	C
25	SEP	80	1200	C
27	SEP	80	1200	RC
29	SEP	80	1200	C
1	OCT	80	1200	C
3	OCT	80	1200	RC
5	OCT	80	1200	C
7	OCT	80	1200	C
9	OCT	80	1200	C
11	OCT	80	1200	C
13	OCT	80	1200	CR
15	OCT	80	1200	C
17	OCT	80	1200	C
19	OCT	80	1200	CR
21	OCT	80	1200	C
23	OCT	80	1200	C
25	OCT	80	1200	C
27	OCT	80	1200	C
29	OCT	80	1200	C
31	OCT	80	1200	CR
2	NOV	80	1200	C
4	NOV	80	1200	C
6	NOV	80	1200	C
8	NOV	80	1200	C
10	NOV	80	1200	C
12	NOV	80	1200	C
14	NOV	80	1200	C
16	NOV	80	1200	RC
18	NOV	80	1200	C
20	NOV	80	1200	C
22	NOV	80	1200	C
24	NOV	80	1200	C
26	NOV	80	1200	C
28	NOV	80	1200	C
30	NOV	80	1200	C
2	DEC	80	1200	C
4	DEC	80	1200	C
6	DEC	80	1200	C

8	DEC	80	1200	C
10	DEC	80	1200	C
12	DEC	80	1200	C
14	DEC	80	1200	CR
16	DEC	80	1200	CR
18	DEC	80	1200	CR
20	DEC	80	1200	C
22	DEC	80	1200	C
24	DEC	80	1200	C
26	DEC	80	1200	C
28	DEC	80	1200	C
30	DEC	80	1200	C

```
12 APR 86 1200      C
14 APR 86 1200      C
16 APR 86 1200      C
18 APR 86 1200      C
20 APR 86 1200      C
22 APR 86 1200     CR
24 APR 86 1200     CR
26 APR 86 1200      C
28 APR 86 1200      C
30 APR 86 1200      C
 2 MAY 86 1200      C
 4 MAY 86 1200      C
 6 MAY 86 1200      C
 8 MAY 86 1200      C
10 MAY 86 1200      C
12 MAY 86 1200      C
14 MAY 86 1200      C
16 MAY 86 1200      C
18 MAY 86 1200      C
20 MAY 86 1200      C
22 MAY 86 1200     CR
24 MAY 86 1200     CR
26 MAY 86 1200      C
28 MAY 86 1200      C
30 MAY 86 1200      C
 1 JUN 86 1200      C
 3 JUN 86 1200      C
 5 JUN 86 1200      C
 7 JUN 86 1200      C
 9 JUN 86 1200      C
11 JUN 86 1200      C
13 JUN 86 1200      C
15 JUN 86 1200     CR
17 JUN 86 1200     CR
19 JUN 86 1200      C
21 JUN 86 1200      C
23 JUN 86 1200      C
25 JUN 86 1200      C
27 JUN 86 1200      C
29 JUN 86 1200     CR
 1 JUL 86 1200      C
 3 JUL 86 1200      C
 5 JUL 86 1200      C
 7 JUL 86 1200      C
 9 JUL 86 1200      C
11 JUL 86 1200      C
13 JUL 86 1200      C
15 JUL 86 1200      C
17 JUL 86 1200      C
19 JUL 86 1200      C
21 JUL 86 1200      C
23 JUL 86 1200      C
25 JUL 86 1200      C
27 JUL 86 1200      C
29 JUL 86 1200      C
31 JUL 86 1200      C
 2 AUG 86 1200      C
 4 AUG 86 1200      C
 6 AUG 86 1200      C
 8 AUG 86 1200      C
```

```
10 AUG 86 1200      C
12 AUG 86 1200      C
14 AUG 86 1200     RC
16 AUG 86 1200      C
18 AUG 86 1200      C
20 AUG 86 1200      C
22 AUG 86 1200      C
24 AUG 86 1200      C
26 AUG 86 1200      C
28 AUG 86 1200      C
30 AUG 86 1200      C
 1 SEP 86 1200      C
 3 SEP 86 1200      C
 5 SEP 86 1200      C
 7 SEP 86 1200      C
 9 SEP 86 1200       C
11 SEP 86 1200       C
13 SEP 86 1200       C
15 SEP 86 1200      CR
17 SEP 86 1200       C
19 SEP 86 1200       C
21 SEP 86 1200       C
23 SEP 86 1200      CR
25 SEP 86 1200       C
27 SEP 86 1200        C   R
29 SEP 86 1200         C   R
 1 OCT 86 1200           C  R
 3 OCT 86 1200          CR
 5 OCT 86 1200         C  R
 7 OCT 86 1200        CR
 9 OCT 86 1200       CR
11 OCT 86 1200       CR
13 OCT 86 1200       CR
15 OCT 86 1200      CR
17 OCT 86 1200      CR
19 OCT 86 1200      CR
21 OCT 86 1200      CR
23 OCT 86 1200      CR
25 OCT 86 1200      C
27 OCT 86 1200      C
29 OCT 86 1200      CR
31 OCT 86 1200     CR
 2 NOV 86 1200     CR
 4 NOV 86 1200     C
 6 NOV 86 1200     C
 8 NOV 86 1200     C
10 NOV 86 1200     C
12 NOV 86 1200     C
14 NOV 86 1200    CR
16 NOV 86 1200    C
18 NOV 86 1200    C
20 NOV 86 1200    C
22 NOV 86 1200    C
24 NOV 86 1200    C
26 NOV 86 1200    C
28 NOV 86 1200   RC
30 NOV 86 1200   C
 2 DEC 86 1200   C
 4 DEC 86 1200   C
 6 DEC 86 1200   C
```

```
 8 DEC 88 1200  .C
10 DEC 88 1200  .C
12 DEC 88 1200  .C
14 DEC 88 1200  .C
16 DEC 88 1200  .C
18 DEC 88 1200  .C
20 DEC 88 1200  .C
22 DEC 88 1200  .C
24 DEC 88 1200  RC
26 DEC 88 1200  RC
28 DEC 88 1200  C
30 DEC 88 1200  C
 1 JAN 89 1200  C
 3 JAN 89 1200  CR
 5 JAN 89 1200  CR
 7 JAN 89 1200  CR
 9 JAN 89 1200  CR
11 JAN 89 1200  CR
13 JAN 89 1200  C
15 JAN 89 1200  C
17 JAN 89 1200  C
19 JAN 89 1200  RC
21 JAN 89 1200  C
23 JAN 89 1200  RC
25 JAN 89 1200  C
27 JAN 89 1200  C
29 JAN 89 1200  C
31 JAN 89 1200  C
 2 FEB 89 1200  CR
 4 FEB 89 1200  CR
 6 FEB 89 1200  CR
 8 FEB 89 1200   C
10 FEB 89 1200  CR
12 FEB 89 1200  RC
14 FEB 89 1200  C
16 FEB 89 1200  C
18 FEB 89 1200  C
20 FEB 89 1200  C
22 FEB 89 1200  C
24 FEB 89 1200  C
26 FEB 89 1200  C
28 FEB 89 1200  C
 2 MAR 89 1200  C
 4 MAR 89 1200  C
 6 MAR 89 1200  CR
 8 MAR 89 1200  CR
10 MAR 89 1200  .C
12 MAR 89 1200  .C
14 MAR 89 1200  .C
16 MAR 89 1200  .C
18 MAR 89 1200  .C
20 MAR 89 1200  .C
22 MAR 89 1200  .C
24 MAR 89 1200  .C
26 MAR 89 1200  .C
28 MAR 89 1200  .C
30 MAR 89 1200  .CR
 1 APR 89 1200   .C
 3 APR 89 1200   .CR
 5 APR 89 1200    .C
```

```
 7 APR 89 1200     .C
 9 APR 89 1200      .C
11 APR 89 1200       .RC
13 APR 89 1200           .CR
15 APR 89 1200               .C  .R
17 APR 89 1200                 .C     .R
19 APR 89 1200                     .C   .R
21 APR 89 1200                     .C   .R
23 APR 89 1200                   .C R
25 APR 89 1200                 .RC
27 APR 89 1200               .R  .C
29 APR 89 1200               .R .C
 1 MAY 89 1200                 .C
 3 MAY 89 1200                .RC
 5 MAY 89 1200              .RC
 7 MAY 89 1200             .CR
 9 MAY 89 1200            .C
11 MAY 89 1200           .C
13 MAY 89 1200          .CR
15 MAY 89 1200         .CR
17 MAY 89 1200        .CR
19 MAY 89 1200       .CR
21 MAY 89 1200       .C
23 MAY 89 1200      .C
25 MAY 89 1200      .CR
27 MAY 89 1200      .C
29 MAY 89 1200      .C
31 MAY 89 1200      .C
 2 JUN 89 1200      .CR
 4 JUN 89 1200      .CR
 6 JUN 89 1200      .C
 8 JUN 89 1200      .C
10 JUN 89 1200      .C
12 JUN 89 1200       .C
14 JUN 89 1200      .RC
16 JUN 89 1200       .C
18 JUN 89 1200     .C
20 JUN 89 1200    .RC
22 JUN 89 1200    .C
24 JUN 89 1200    .C
26 JUN 89 1200    .C
28 JUN 89 1200   .C
30 JUN 89 1200   .C
 2 JUL 89 1200   .C
 4 JUL 89 1200   .C
 6 JUL 89 1200   .C
 8 JUL 89 1200   .C
10 JUL 89 1200   .C
12 JUL 89 1200   .C
14 JUL 89 1200   .C
16 JUL 89 1200   .C
18 JUL 89 1200  .C
20 JUL 89 1200  .C
22 JUL 89 1200  .C
24 JUL 89 1200  .C
26 JUL 89 1200  .C
28 JUL 89 1200  .C
30 JUL 89 1200  .C
 1 AUG 89 1200   .C
 3 AUG 89 1200   .C
```

```
 5 AUG 69 1200      CR
 7 AUG 69 1200      CR
 9 AUG 69 1200      RC
11 AUG 69 1200      R C
13 AUG 69 1200      RC
15 AUG 69 1200      RC
17 AUG 69 1200       C
19 AUG 69 1200       C
21 AUG 69 1200       C
23 AUG 69 1200      C
25 AUG 69 1200      C
27 AUG 69 1200      C
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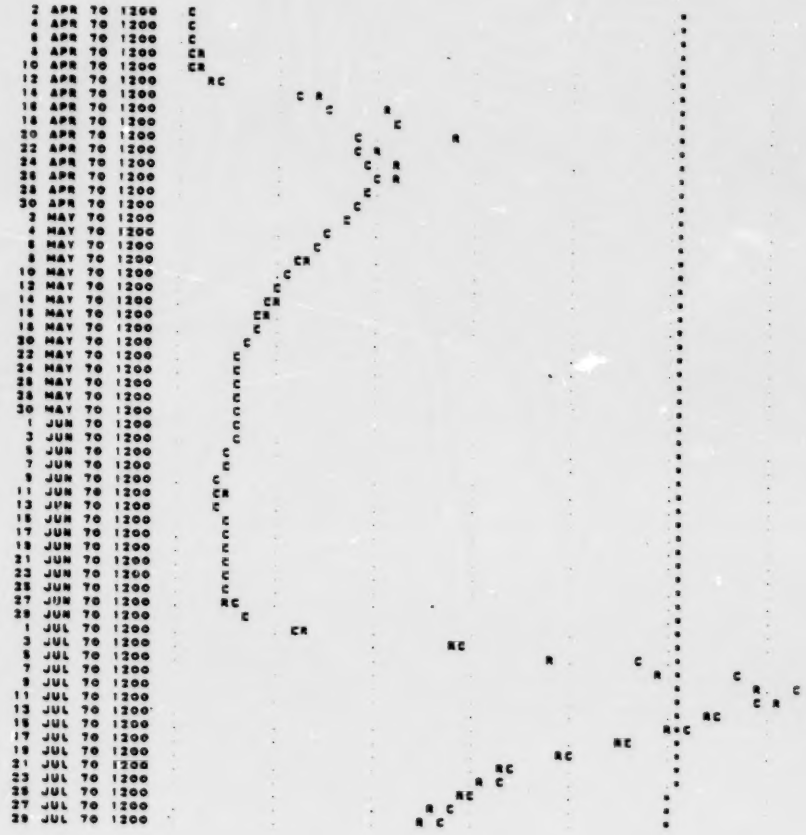
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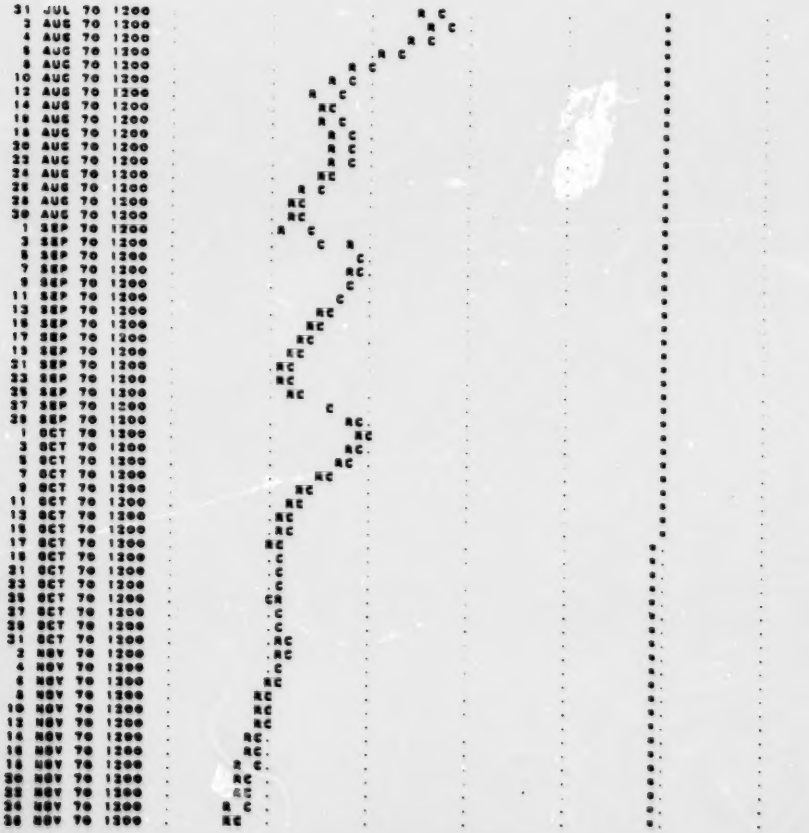
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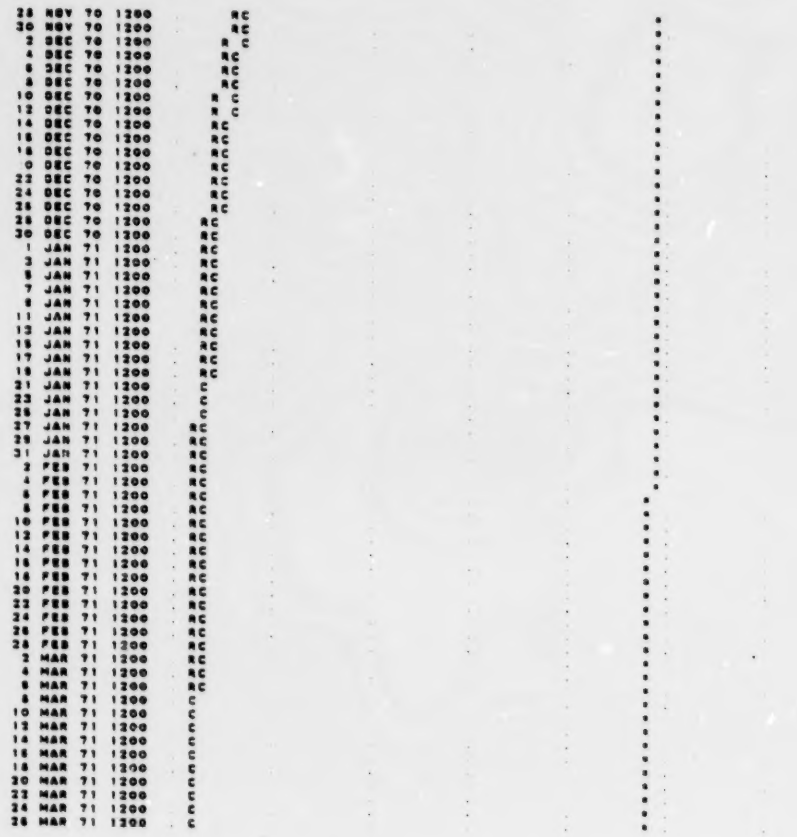
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                                  CHARACTER                                                  NUMBER CONTROL

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                                      R-BEAVER R  AT COLD LAKE 06AD006                         52.6   0
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                                      *-DUMMY RES  (DIFF) AT BEAVER RIVER AT COLD LA          726.2   E
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APPENDIX B

GROUND WATER RESOURCES

A Report Prepared By
MLM GROUND-WATER ENGINEERING

MLM Ground-Water Engineering

#209 - 200 Carnegie Drive, St. Albert, Alberta, Canada T8N 3K1

Phone: (403) 458-8383

May 30, 1983

Alberta Environment
Planning Division
9820 - 106th Street
EDMONTON, AB
T5K 2J6

Attention: Ron Hicks, P.Eng.

Dear Mr. Hicks:

Re: Ground-Water Resources
Cold Lake - Beaver River Basin

We have the pleasure of submitting our final report entitled, "Ground-Water Resources, Cold Lake - Beaver River Basin". The report presents a summary of the information regarding the geology and hydrogeology of the major aquifers in the area. Estimates of ground-water availability are given along with the adequacy of the supplies for the various users.

We trust this report is satisfactory for your needs at this time.

Yours truly,

MLM GROUND-WATER ENGINEERING

M. G. Mateyk, P. Geol.
Project Manager

llc

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APPENDIX A Water Quality Analyses

1.0 INTRODUCTION

1.1 Purpose of Study

Water use is becoming a critical issue within the Cold Lake - Beaver River Basin as a result of the proposed development of the Cold Lake oil sands. Combining this with the associated population growth and increasing recreational land use, sometimes conflicting demands may be placed on the surface and ground-water resources of the basin. In order to facilitate orderly management of the water resources, Alberta Environment is developing a long-term framework plan for the Cold Lake - Beaver River Basin.

In order to address the various issues of the management plan, a multi-component study was formulated by Alberta Environment. This report deals with the ground-water resources part of the water supply component. The terms of reference, under which the study was conducted, stipulated that MLM should:

- Review all available ground-water data, including any preliminary results of Alberta Environment's 1981 test drilling and observation well program.

- Prepare an overview of ground water as a water supply source in the study area and submit this overview in a letter report.

- Following the completion of Alberta Environment's 1981 ground-water program, assess the locations and rate of regional ground-water recharge and discharge, the direction and rate of regional ground-water movement, and the potential location, quality and quantity of ground-water.

- Review the various water withdrawal demand scenarios prepared for time horizons 1985, 2000 and 2015.

- Determine the existing and potential significance of ground water as a water supply source on a local and regional scale and identify any future data collection requirements where supply is significant.

- Devise a procedure and account for ground-water/surface water interaction where data is adequate and the interaction is critical to the surface water supply balance.

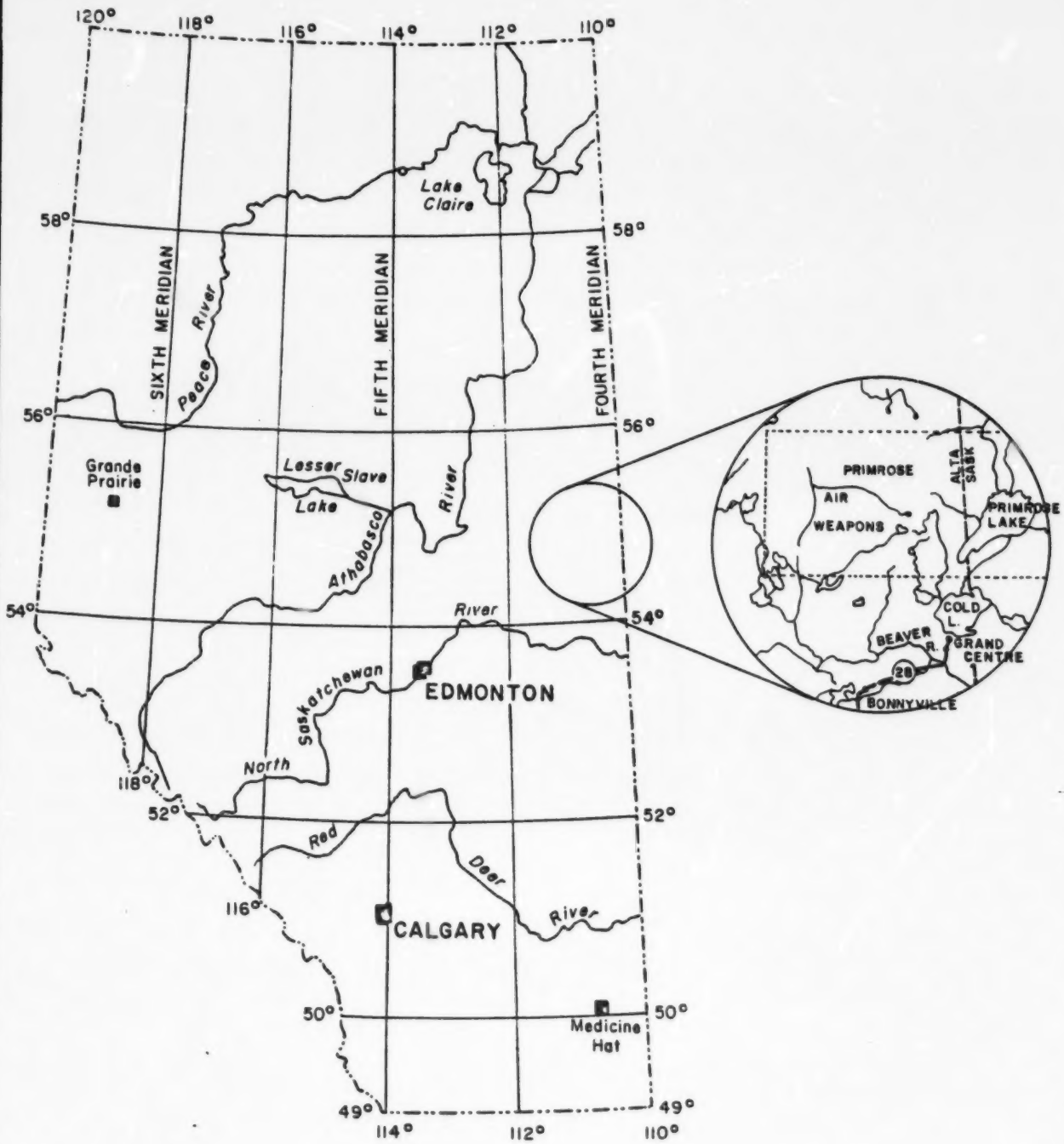
1.2 Location

The Cold Lake - Beaver River Basin is located in East Central Alberta (Figure 1). For the purpose of this study, ground-water resources were studied for the portions of the study area within Alberta.

1.3 Data Base

Several ground-water investigations have been previously conducted within the study area. The Alberta Research Council has completed a regional overview of the hydrogeology of the area as part of their hydrogeological reconnaisance map series. These maps display ground-water probalities (expected average well yields), chemistry, and certain aspects of the flow system for map areas delineated by the NTS. The three reports which each cover a portion of the study area are:

- Hydrogeology of the Tawatinaw Area, Alberta (NTS 83I)
- Hydrogeology of the Waterways - Winefred Lake Area, Alberta (NTS 74D and 73M)
- Hydrogeology of the Sand River Area, Alberta (NTS 73L)



JOB No. B-171-12	LOCATION OF STUDY AREA	DATE FEB/82
SCALE		FIGURE 1

MLM Ground-Water Engineering

A number of detailed site specific ground-water investigations have been conducted by various consulting companies for heavy oil pilot plants and municipal use. These studies provided data on aquifer hydraulic parameters. Alberta Environment has also conducted a number of site specific investigations, mainly as a part of the Northern Water Supply Program. These reports contain data on hydraulic parameters and ground-water quality.

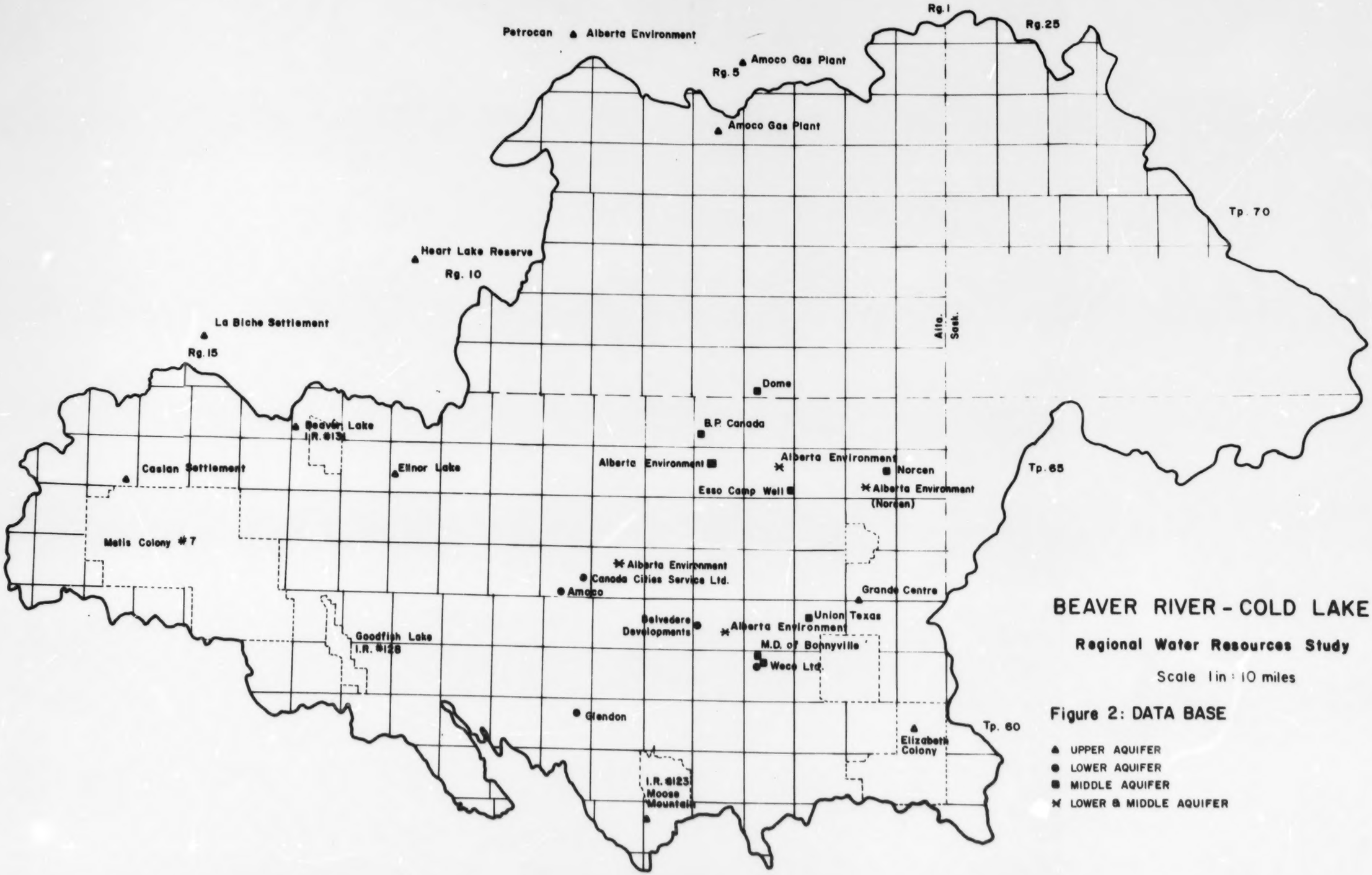
Alberta Environment installed two observation wells in the vicinity of Bonnyville (1-15-62-5-4) in 1977. Two addiitonal wells were installed near Bourque Lake (4-26-65-4-4) in 1980. The hydrographs for these observation wells were provided by the Ground-Water Branch.

Recently, the Ground-Water Branch, under the direction of Chris Gold, completed an inventory and compilation of geologic data in the study area. The objective of this study is to delineate the bedrock chanels in the region and to define the various surficial aquifers associated with the channels. Currently, the program is at a stage where test drilling is being conducted to fill in various gaps in the data base.

The locations of the most important site specific studies are presented in Figure 2, while the type of information derived from the reports is summarized in Table 1.

1.4 Acknowledgements

Special thanks for assistance in preparing this report is due to a number of individuals. Mr. Ron Hicks of Planning Division, ensured that data from other components of the study needed for this report were forthcoming. Mr. Vern Carlson, Branch Head of the Ground-water



BEAVER RIVER - COLD LAKE

Regional Water Resources Study

Scale 1 in : 10 miles

Figure 2: DATA BASE

- ▲ UPPER AQUIFER
- ● LOWER AQUIFER
- ■ MIDDLE AQUIFER
- ✱ LOWER & MIDDLE AQUIFER

MLM GROUND-WATER ENGINEERING

TABLE 1

SUMMARY OF SITE SPECIFIC GROUND-WATER INVESTIGATIONS

Well Owner	Location	Potential Water Use	Work Conducted by	Type of Information
Amoco	7-4-63-8-4	Pilot Plant	Consultant	Test drilling, aquifer hydraulic properties, water quality
Canada Cities Ltd.	6-13-63-8-4	Pilot Plant	Consultant	"
M.D. of Bonnyville	SE32-61-4-4	Municipal	Consultant	"
Suncor (Weco)	SW38-61-4-4	Pilot Plant	"	"
Belvedere Developments	SW19-62-5-4	Industrial	"	"
Village of Glendon	SE26-60-8-4	Municipal	"	"
Union Texas	13&14-20-62-3-4	Pilot Plant	"	"
Imperial Oil	NE1-65-4-4	Construction Camp	"	"
B.P.	9-7-66-5-4	Pilot Plant	"	"
Norcen	12-24-65-2-4	Pilot Plant	"	"
Alberta Environment (Norcen)	SW9-65-2-4	Observation Well	Alberta Environment	Aquifer hydraulic properties
Dome	NE5-67-4-4	Pilot Plant	Consultant	Test drilling, aquifer hydraulic properties, water quality

Table 1 continued...

Well Owner	Location	Potential Water Use	Work Conducted by	Type of Information
Petro Canada	10-19-23-7-4	Pilot Plant	Consultant	Aquifer hydraulic properties
Alberta Environment	10-19-23-7-4	Ground-Water Investigation	Alberta Environment	Test drilling, aquifer hydraulic properties, water quality
Alberta Environment	1-15-62-5-4	Observation Well	"	Test Drilling and observation well installation
Alberta Environment	4-26-65-4-4	Observation Well	"	Aquifer hydraulic properties
Alberta Environment	SW28-65-5-4	Observation Well	"	"

Rights Branch, allowed access to the various files within the study area. Mr. Chris Gold, of the Groundwater Branch, generously provided his detailed information on the bedrock topography and surficial geology.

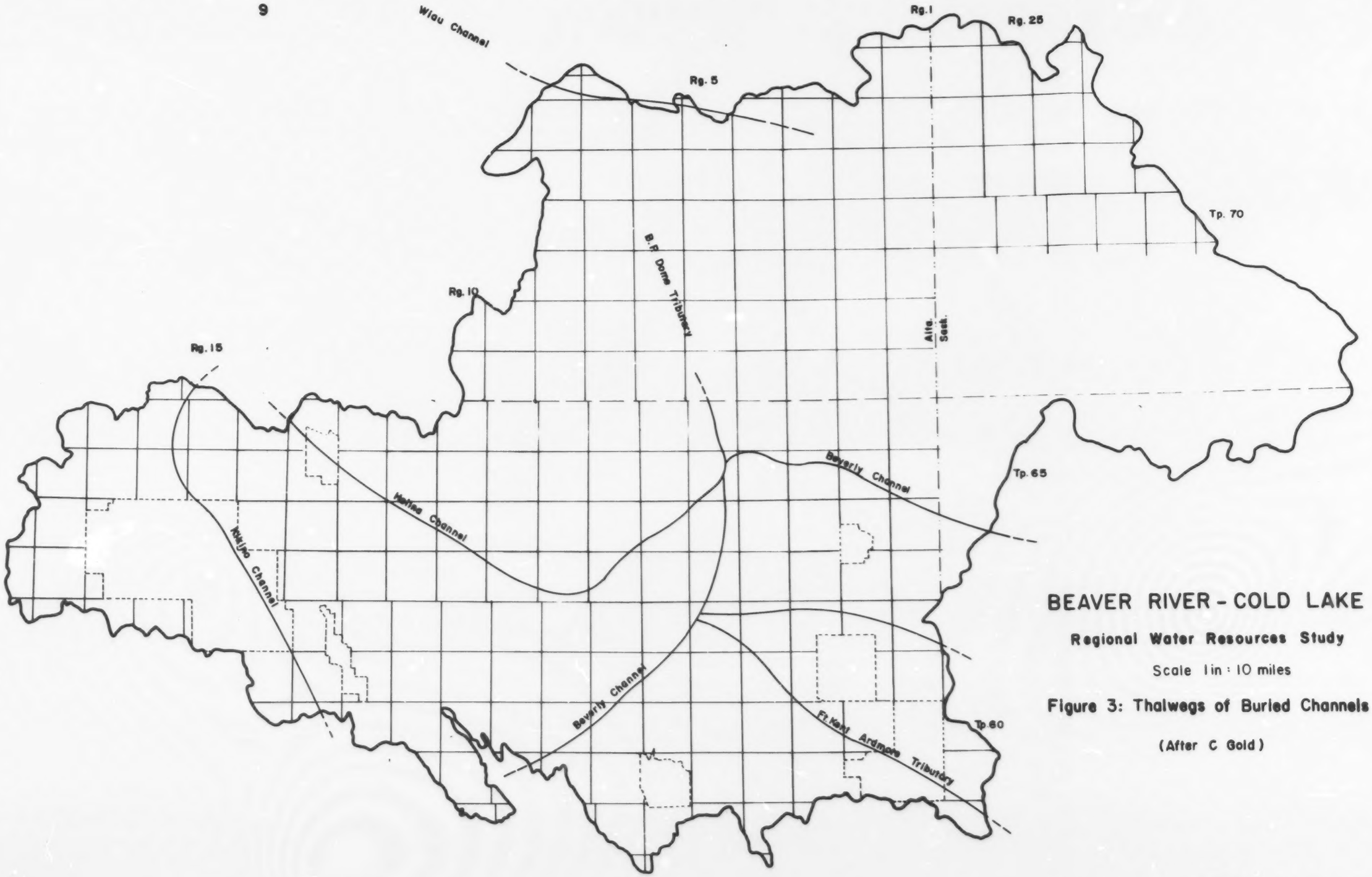
2.0 AQUIFER GEOLOGY

2.1 General Statement

The geology of the aquifers in the Cold Lake - Beaver River area can be best understood in light of the area's glacial and late preglacial history.

During the late Quaternary, the landscape was dissected by a system of rivers which drained from the Cordillera toward the east. Eventually, a mature land surface, characterized by streams running in broad, flat bottomed valleys evolved, the thalwegs of which are shown in Figure 3. These streams ran at or near grade, reworking sands and gravels in the valley bottoms, and bringing about a high degree of sorting in the sediments. The granular materials found in these bedrock valleys, lying directly upon the bedrock, were transported from the Cordillera, and therefore contain a high percentage of siliceous material (chert, quartz, quartzite).

The glaciers which moved over the country during the Pleistocene Epoch brought about a drastic change in the land surface. The preglacial bedrock valleys were filled



BEAVER RIVER - COLD LAKE

Regional Water Resources Study

Scale 1 in : 10 miles

Figure 3: Thalwegs of Buried Channels

(After C Gold)

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in with till, especially where the direction of glacial movement was at a large angle to the trend of the valley. During glacial melting, the till was released from its ice matrix and left as an unsorted mass. The valleys served as drainage channels for the meltwaters, which reworked the tills, carrying away the silt and clay fraction, and leaving behind the sand, gravel, and larger fractions. Because of this, the accumulations of sorted granular materials derived from reworked till are thickest in the valleys, and grow thinner toward the valley flanks. Because there were a number of glacial advances and recessions during the Pleistocene, these layers are in places, quite numerous.

2.2 Upper Aquifer

In this report, the name "upper aquifer" is applied to a series of discontinuous, poorly-sorted, intertill sands and gravels found generally within the upper 45 metres or so of overburden. These sand and gravel layers are of glacial origin. They are lensitic, and the thickness of a single layer is seldom more than 3 metres, although their aggregate thickness may be as much as 15 metres. The mineralogy of the upper aquifer relects the provenance of the tills from which the sands and gravels were derived. Granitic and metamorphic rock fragments from the Precambrian Shield are preponderant. Carbonate minerals are also present, derived from the Paleozoic sedimentary rocks to the northeast.

The upper aquifer has been exploited extensively throughout the study area and northeastern Alberta in general, for domestic and agricultural water supply. It has been particularly useful where buried valleys do not exist, and no ground water is available from the bedrock. In places, these intertill layers are the only

source of ground water. Because of this, and despite a generally low observed individual well yield, the regional importance of the upper aquifer cannot be denied. However, in the context of this report, we are concerned with high-yield industrial and municipal ground-water supplies. For this reason, the upper aquifer is not discussed in as much detail as are the two deeper, major aquifers in the region.

2.3 Middle Aquifer

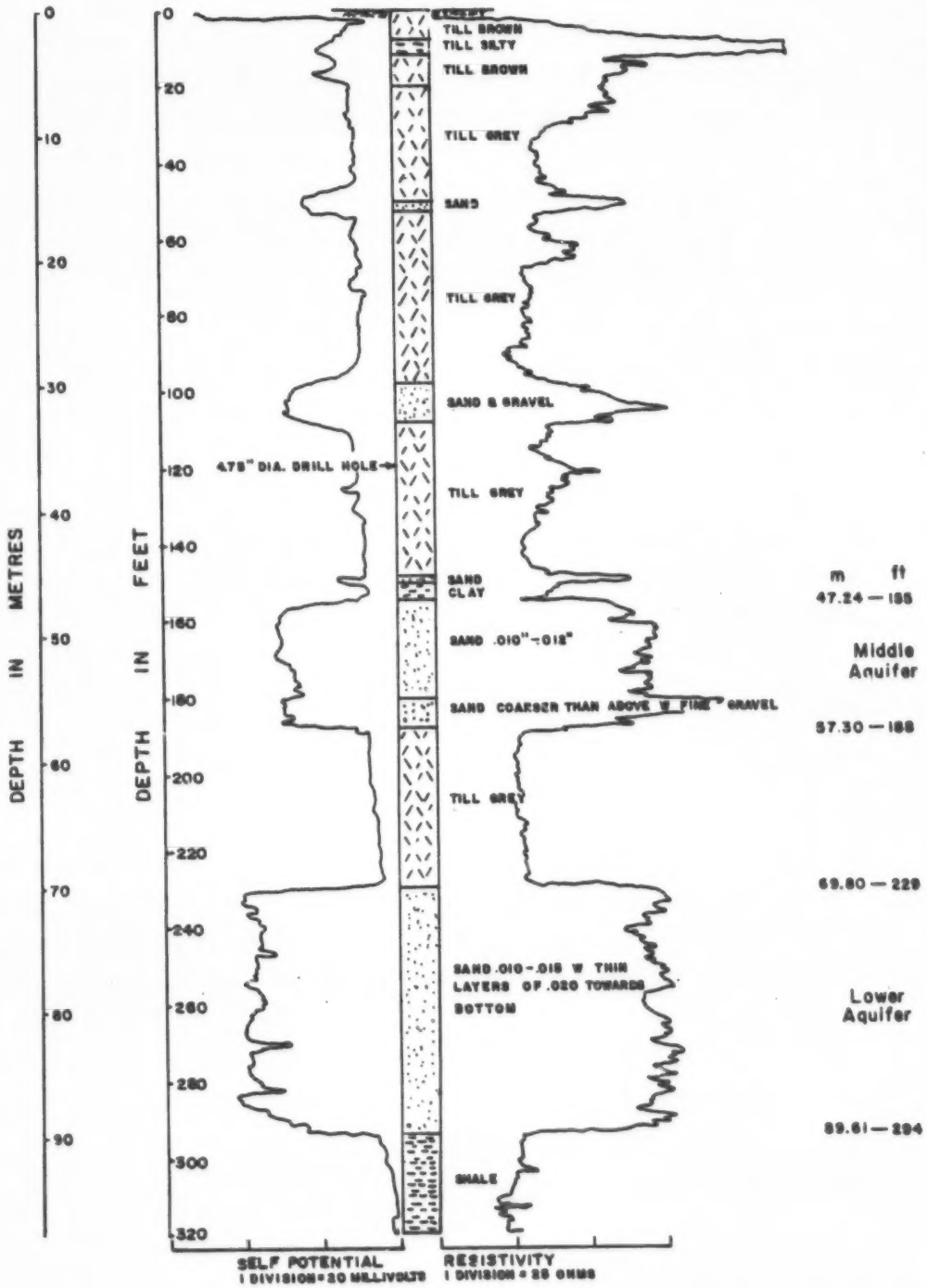
The uppermost of the two major aquifers occupying the buried preglacial channels of the study area, is an intertill unit termed the "Middle Aquifer" in this report. An isopach map of the aquifer was prepared from the crossections of the Alberta Environment Study, and is shown in Figure 4 (pocket).

Beverly Channel

In a water supply investigation for the Village of Glendon (NW¼-Sec4-Tp61-Rge8-W4M), Baydack and Render (1981) drilled a total of seven test holes into the Beverly Channel.

The best definition of the middle aquifer in that area is seen in SE¼-Sec26-Tp6-Rge8-W4M. A typical stratigraphic section in this area is shown in Figure 5.

In the Beverly Channel here, the Middle Aquifer reaches a maximum thickness of up to 12.2 metres. The sands consist of white silica and black chert fragments; a mineralogy which indicates a Cordilleran source. In the Glendon area, the Middle Aquifer extends approximately 3 km outward from the centre of the Beverly Channel, and consequently, is not encountered beneath the Village of Glendon (NW¼-Sec.4-Tp.61-Rge.8-W4M).



JOB Nº B-171-12	TYPICAL STRATIGRAPHIC SECTION	DATE MARCH/82
SCALE	GLENDON (SE 26-60-8-4)	FIGURE 5

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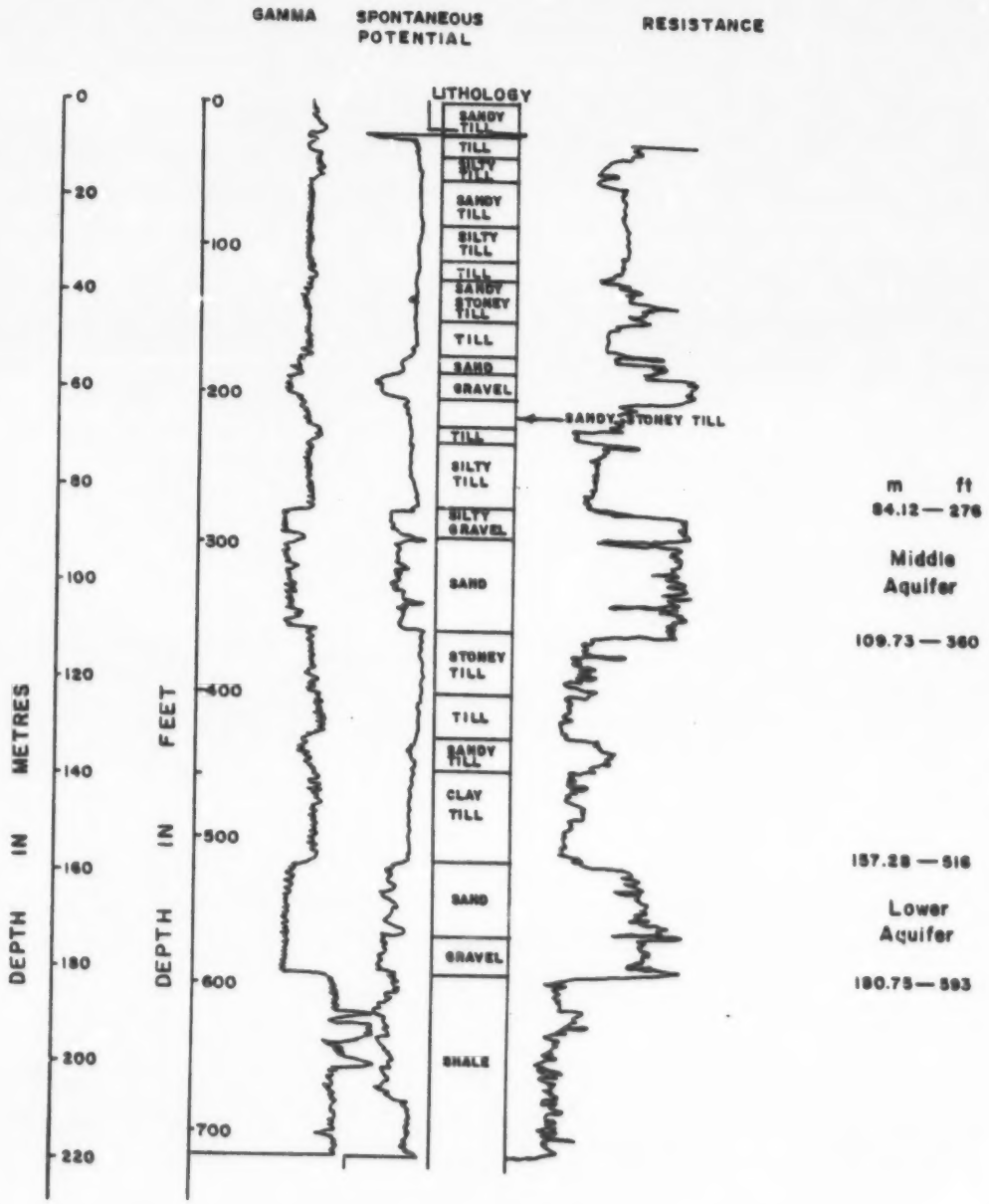
An observation well, drilled in the Bourque Lake area (4-26-65-5-4) by Alberta Environment (1978) encountered the Middle Aquifer over the depth interval 84 to 109 metres (510 to 536 m a.m.s.l.). The aquifer consists of interlayered sandy silt, overlying fine to coarse-grained sand. The log of this well (Figure 6) shows a very good definition of the Middle Aquifer.

Further east, on LSD12-Sec24-Tp65-Rge2-W4M, the Middle Aquifer is very well represented as a 13.7 metre thick layer of brown sand and gravel of an unspecified mineralogic content, in a well drilled and tested for Norcen Ltd. (Hydrogeological Consultants Ltd., 1976). A second Norcen well, located on SW9-Tp65-Rge2-W4M, and tested by Alberta Environment, encountered the Middle Aquifer over the depth interval 65.5 to 75.3 metres. The Middle Aquifer pinches out to the north, and was not encountered in a test hole drilled for Norcen Ltd. on Sec6-Tp77-Rge2-W4M (Hydrogeological Consultants Ltd., 1976).

B.P. - Dome Tributary

British Petroleum's Cold Lake Pilot plant, situated on LSD9-Sec7-Tp66-Rge5-W4M utilizes ground water from the flank of a north-trending tributary of the Beverly Channel. This tributary has been termed the B.P. - Dome Tributary for the purposes of this report. The Middle Aquifer is only about 7.6 metres thick in the vicinity of LSD9-Sec7, and is located directly on the bedrock surface.

The report by Hydrogeological Consultants Ltd. (1976) indicates that as one goes eastward from the B.P. plant site toward the centre of the tributary channel, the Middle Aquifer grows progressively thicker, better-sorted, and more well-defined. A similar trend is seen going in a southerly direction, toward the Beverly Channel. On the west side of the tributary, in NE¼-Sec5½Tp67-Rge4-W4M, a well completed for Dome Petroleum Ltd. by Stanley



JOB Nº B-171-12	ELECTRIC LOG — BOURQUE LAKE OBSERVATION WELL	DATE MARCH/82
SCALE		FIGURE 6

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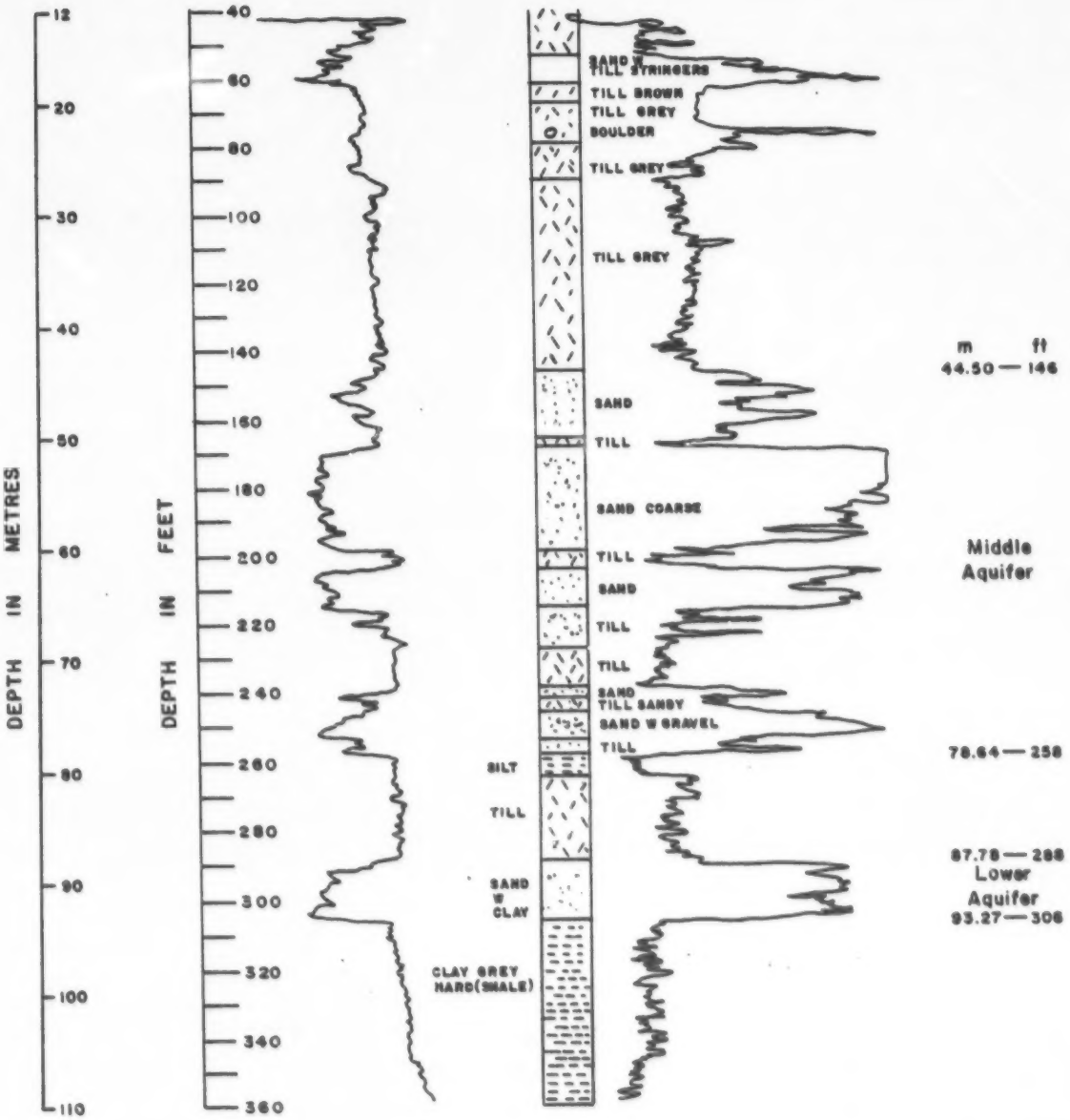
and Associates (1981) utilizes approximately 13.7 metres of interlayered coarse-grained sand and fine gravels present over the depth interval 73 to 87 metres. The sands are made up of rounded, well sorted quartz, quartzite, and chert fragments. It is separated from the bedrock by approximately 36.5 metres of glacial till. The exact relationship between the aquifer here and that utilized by B.P. is not known.

Further south, near the confluence of the B.P. - Dome Tributary, and the Beverly Channel, an observation well, drilled and tested by Alberta Environment, on SW¼-Sec28-Tp65-Rge5-W4M encountered the Middle Aquifer over the depth interval 114.6 to 130.8 metres. The thickness and the well-developed aspect of the Middle Aquifer at this location can be attributed to the proximity of the test hole to the centre of the Beverly Channel.

Helina Channel

On LSD7-Sec4-Tp63-Rge8-W4M, a well drilled by Amoco Canada Ltd. encountered a series of sand and gravel layers in the Helina Channel. A log of this hole (Figure 7) shows that the Middle Aquifer is less definable as a single unit than in the Beverly Channel. The aquifer consists of two distinct sand and gravel layers. The lower-most is 5.5 metres thick and appears to be a poorly sorted interlayering of sand and till. The uppermost part is much thicker (approximately 28 metres) and is separated from the lower by a 6-metre layer of till. The upper layer also consists of interlayered sand and till, although it appears to be very well sorted throughout one 9-metre interval. The lithology is not specified in the Amoco Report (Elk Point Drilling Corp., 1979).

The bimodal nature of the Middle Aquifer in the Helina Channel is also seen in a well drilled for Canada Cities Service on LSD6-Sec13-Tp63-Rge8-W4M (UMA Group,



JOB Nº B-171-12	ELECTRIC LOG OF AMOCO WELL	DATE MARCH/82
SCALE	(7-4-63-8-4)	FIGURE 7

MLM Ground-Water Engineering

1981). Here, the log shows less deflection than in the Amoco well, but the stratigraphic succession is very similar.

In a well completed by Alberta Environment in March, 1982, on SW¼-Sec27-Tp63-Rge7-W4M, the Middle Aquifer is represented by a 61-metre zone of sand found over the interval 53.6 to 59.7 metres, and a 5.8-metre zone in the interval 77.4 to 83.2 metres (R. Hicks, pers. comm.). At this location, the Middle Aquifer appears to be more clearly demarcated from the contiguous till units than is observed in the Amoco well (LSD7-Sec4-Tp63-Rge8-W4M) and the bimodality of the aquifer is well demonstrated.

The obvious differences between the Middle Aquifer in the Helina Channel, and the better-defined examples seen in the Beverly Channel (Bourque Lake observation well; Town of Glendon) must be taken as an indication that while we may find it expedient to simplify the geology of the area for the purposes of presentation, the presentation may not be totally accurate. The series of geological events, which resulted in the observed distribution of aquifer materials at different locations, were not the same throughout the entire region. Such factors as ice front position, the trend of the bedrock channel, and the local quality and type of material dropped from the ice mass, varied from place to place, and over time. Therefore, the stratigraphic sequence from place to place may commonly reflect large, regional depositional events, but the smaller events will be reflected only locally.

Ft. Kent - Ardmore Tributary Channel

The Ft. Kent - Ardmore Tributary shown in Figure 3 was originally introduced in a report by Geoscience Consultants Ltd. (1978) for World Wide Energy Co. Ltd. (WECO), who had commissioned a test-drilling program on sections 28 and 29, Tp61-Rge4-W4M.

On SW¼-Sec28-Tp61-Rge4-W4M, the Middle Aquifer is encountered within the depth interval 46 to 67 metres (Figure 8). A test hole drilled on LSD9-Sec29-Tp61-Rge4-W4M shows that the aquifer thins from 21 to 18 metres, and becomes more clayey to the northwest of section 28. A well belonging to the M.D. of Bonnyville, situated on LSD8-Sec32-Tp61-Rge4-W4M is completed in the Middle Aquifer, which is 15 metres thick at this location.

Within the Ft. Kent - Ardmore Tributary, the Middle Aquifer is well-defined, and the stratigraphy is similar to that of the Beverly Channel.

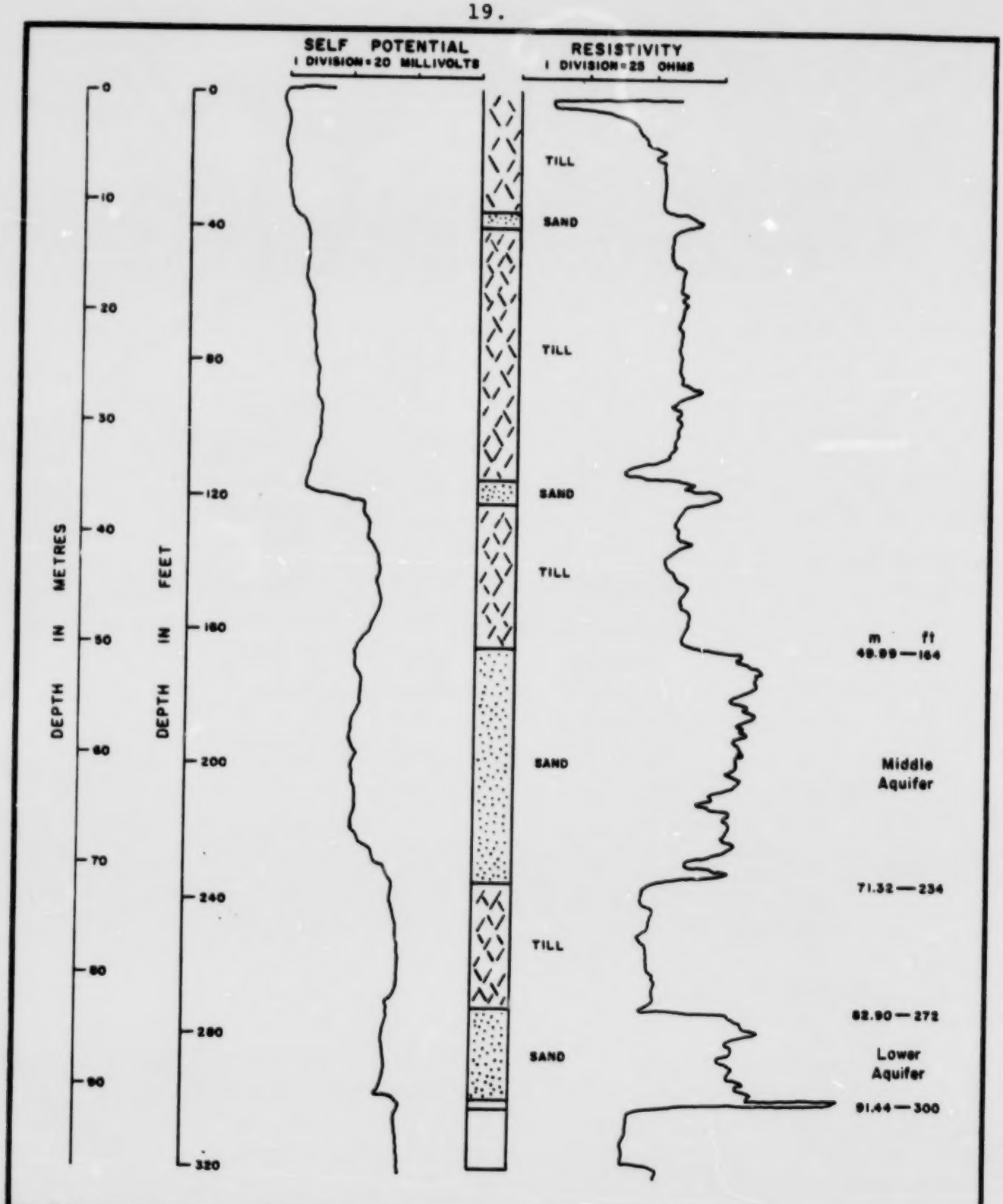
2.4 Lower Aquifer

The Lower Aquifer, which consists of preglacial sand and gravel is often found either in direct contact with the bedrock, or separated from the bedrock by a thin layer of clay. It attains its maximum thickness near the thalweg of the preglacial valleys and tends to pinch out abruptly against the valley walls as one moves away from the centre. An isopach map is shown in Figure 9 (pocket).

The thickness, homogeneity, and degree of sorting in the preglacial alluvium varies somewhat within the confines of the buried channels themselves. These variations however, do not appear to be as pronounced as in the Middle Aquifer. It can be assumed that the deposition of the preglacial alluvium occurred under considerably more stable conditions than that of the glaciofluvial sediments of the Middle and (especially) the Upper Aquifer.

Beverly Channel

Baydack and Render (1981), during their water supply investigation for the Village of Glendon, drilled a number of test holes on Sections 24, 25, 26 and 30, Tp60-



JOB Nº B-171-12	WECO WELL #5 (3-28-61-4W4)	DATE MARCH/82
SCALE		FIGURE 8

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Rge8-W4M and Section 4-Tp61-Rge8-W4M. The electrolog from the main production well is shown in Figure 5. The most favourable development of the lower aquifer was found in SE¼-Sec26-Tp60-Rge8-W4M. At this location, the aquifer is approximately 16.7 metres thick, and lies directly upon the Lea Park shales.

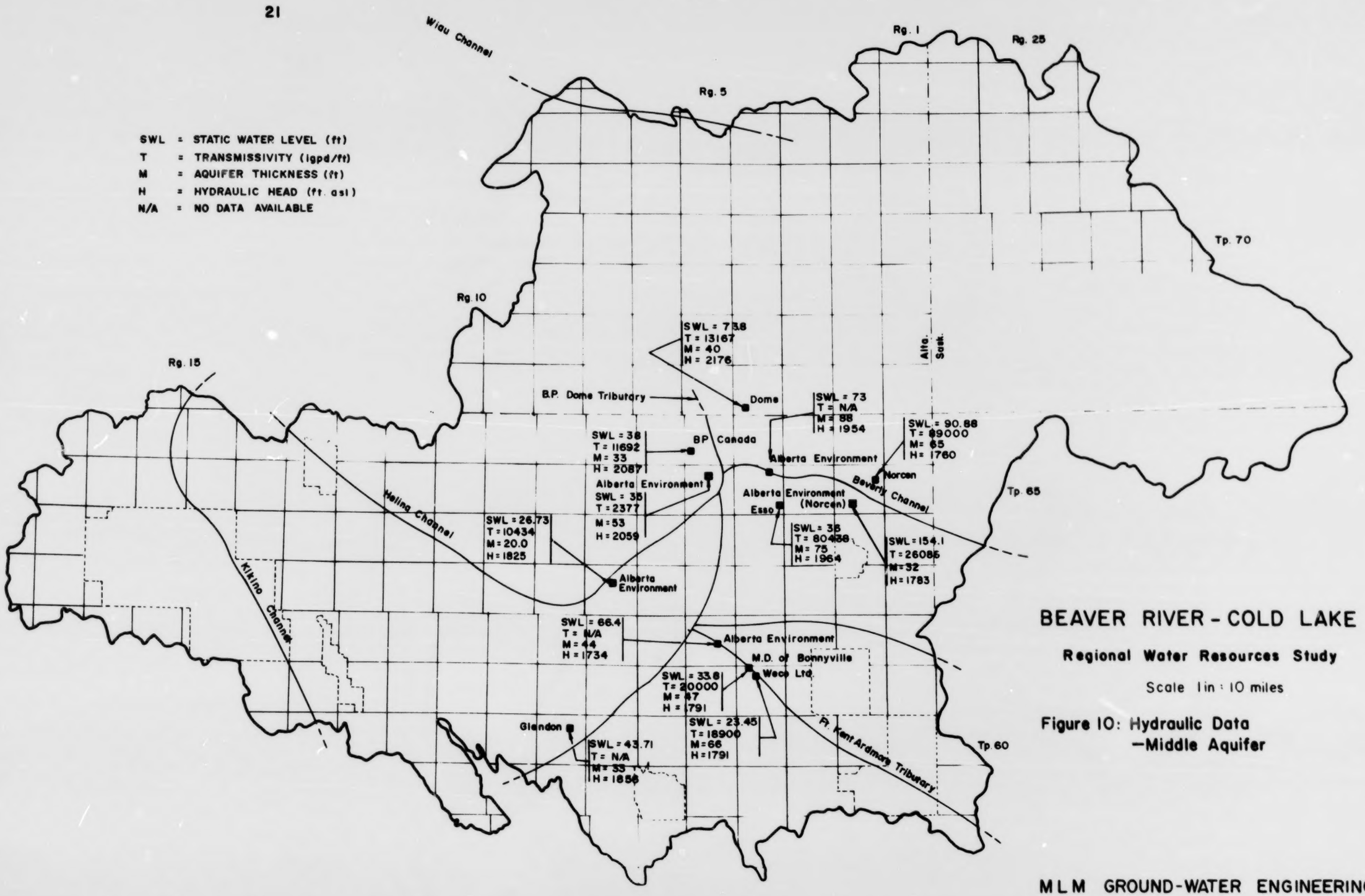
At the Bourque Lake observation well (LSD4-Sec26-Tp65-Rge4-W4M), the Lower Aquifer is well developed. It is approximately 23 metres thick at this location, and is located directly on the bedrock surface (Figure 6).

In the Cold Lake area, the well drilled by Norcen Ltd. on LSD12-Sec4-Tp65-Rge2-W4M shows that the Lower Aquifer is well-developed and appears cleaner and coarser-grained than the Middle Aquifer at that location.

B.P. - Dome Tributary

No evidence of the Lower Aquifer is found in the B.P. and Dome wells (LSD9-Sec7-Tp66-Rge5-W4M, and NE5-TP67-Rge4-W4M, respectively). These two wells are thought to be situated far enough from the centre of the B.P. - Dome Tributary for the Lower Aquifer to have pinched out. The Lower Aquifer is thought however, to reach a thickness of greater than 15 metres toward the centre of the tributary, as indicated on the isopach map (Figure 9). The Alberta Environment well (Figures 2 and 10), located on SW¼-Sec28-Tp65-Rge5-W4M is situated approximately three km west of the suspected confluence of the B.P. - Dome Tributary and the Beverly Channel. This well encountered the Lower Aquifer over the depth interval 147 to 154 metres. According to the field geologist's report (J. Marciniuk, pers. comm.), the aquifer at this point is relatively poorly sorted. No hydrogeologic data on the Lower Aquifer were collected at this location.

SWL = STATIC WATER LEVEL (ft)
T = TRANSMISSIVITY (igpd/ft)
M = AQUIFER THICKNESS (ft)
H = HYDRAULIC HEAD (ft. asl)
N/A = NO DATA AVAILABLE



BEAVER RIVER - COLD LAKE

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Scale 1 in : 10 miles

Figure 10: Hydraulic Data —Middle Aquifer

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Helina Channel

In the Helina Channel, the investigations conducted by Amoco Ltd. and Canada Cities Service Ltd. indicate that the Lower Aquifer is considerably thinner than in the Beverly Channel. In Amoco's test hole (SW¼-Sec4-Tp63-Rge8-W4M), the thickness of the Lower Aquifer is only about 4.87 metres (Figure 7); in the Canada Cities Service well (LSD6-Sec13-Tp63-Rge8-W4M), the thickness is 6 metres.

In the Alberta Environment well completed on SW¼-Sec27-Tp63-Rge7-W4M, the Lower Aquifer is encountered over the depth interval 93 to 106.1 metres. Its thickness here (6.1 metres) is slightly greater than that observed in either the Canada Cities Service, or the Amoco wells. Although the increased thickness is not great, this could be an indication of a general thickening of the Lower Aquifer in the Helina Channel, toward the northeast (Figure 9).

Ft. Kent - Ardmore Tributary

In the Ft. Kent - Ardmore Tributary, the Lower Aquifer appears to be as well defined as in the Beverly Channel. The report by Geoscience Consulting Ltd. (1978), shows electrologs from several test holes drilled in and around SW¼-Sec28-Tp61-Rge4-W4M. In this area, the Lower Aquifer is approximately 8.5 metres thick (Figure 8). On LSD9-Sec29-Tp61-Rge4-W4M it is 4.3 metres thick.

2.5 Wiau Channel

At present, very little is known about the aquifer geology of the Wiau Channel (Figure 3).

Alberta Energy Co. Ltd. is presently conducting a test drilling program, and Alberta Environment has completed a test well.

The Alberta Environment well was drilled on LSD10-Sec29-Tp73-Rge7-W4M to a depth of 308 metres. The well is completed in a fine sand, encountered over the depth interval 270 to 308 metres (C. Gold, pers. comm.).

The overburden is much thicker in the northern part of the study area than in the south. The sand unit encountered by the Alberta Environment well is probably "Lower Aquifer", by virtue of its depth. This is not known for sure however, and more data are required.

3.0 HYDROGEOLOGY

3.1 Aquifer Hydraulic Properties

From limited pumping test data on nine wells, the average value of the hydraulic conductivity of the Middle Aquifer is calculated to be 23.1 m/day. It appears to be hydrologically confined throughout the study area. Since most pumping tests were conducted without observation wells, only one value of the storage coefficient has been calculated for the Middle Aquifer. It is 2.6×10^{-3}.

From eight pumping tests, the average value of the hydraulic conductivity of the Lower Aquifer is calculated to be 20.1 m/day. This aquifer also appears to be hydraulically confined throughout the study area. From work done for the Village of Glendon and Belvedere Developments, the storativity has been calculated to be 2.5×10^{-4}.

The results of pumping tests conducted throughout the region indicate that for the duration of a given test, no hydraulic connection between the Middle and Lower Aquifer is seen. This is not to say however, that on the longer term, an interconnection of the aquifers would not be observed.

In a pumping test conducted for Alberta Environment on their well located on LSD10-Sec29-Tp73-Rge7-W4M, the hydraulic conductivity of the lowermost sand aquifer

in the Wiau Channel, was calculated to be 5.1 m/day, with a storage coefficient of 2×10^{-2}.

The results of pumping tests conducted on wells completed in the Middle and Lower Aquifer are presented in Table 2. The location of the data points and the respective hydraulic parameters for the Middle and Lower Aquifers are shown in Figures 10 and 11, respectively.

3.2 Natural Ground-Water Flow

Values of hydraulic head have been calculated from static water level measurements taken during pumping tests and from observation well records. These are presented in Table 3. Where estimates had to be made, it was assumed that the top of the casing was 0.6 metres (two feet) above ground level and that ground level elevations could be determined from 1:50,000 topographic maps. The hydraulic head data has also been summarized in Figures 10 and 11.

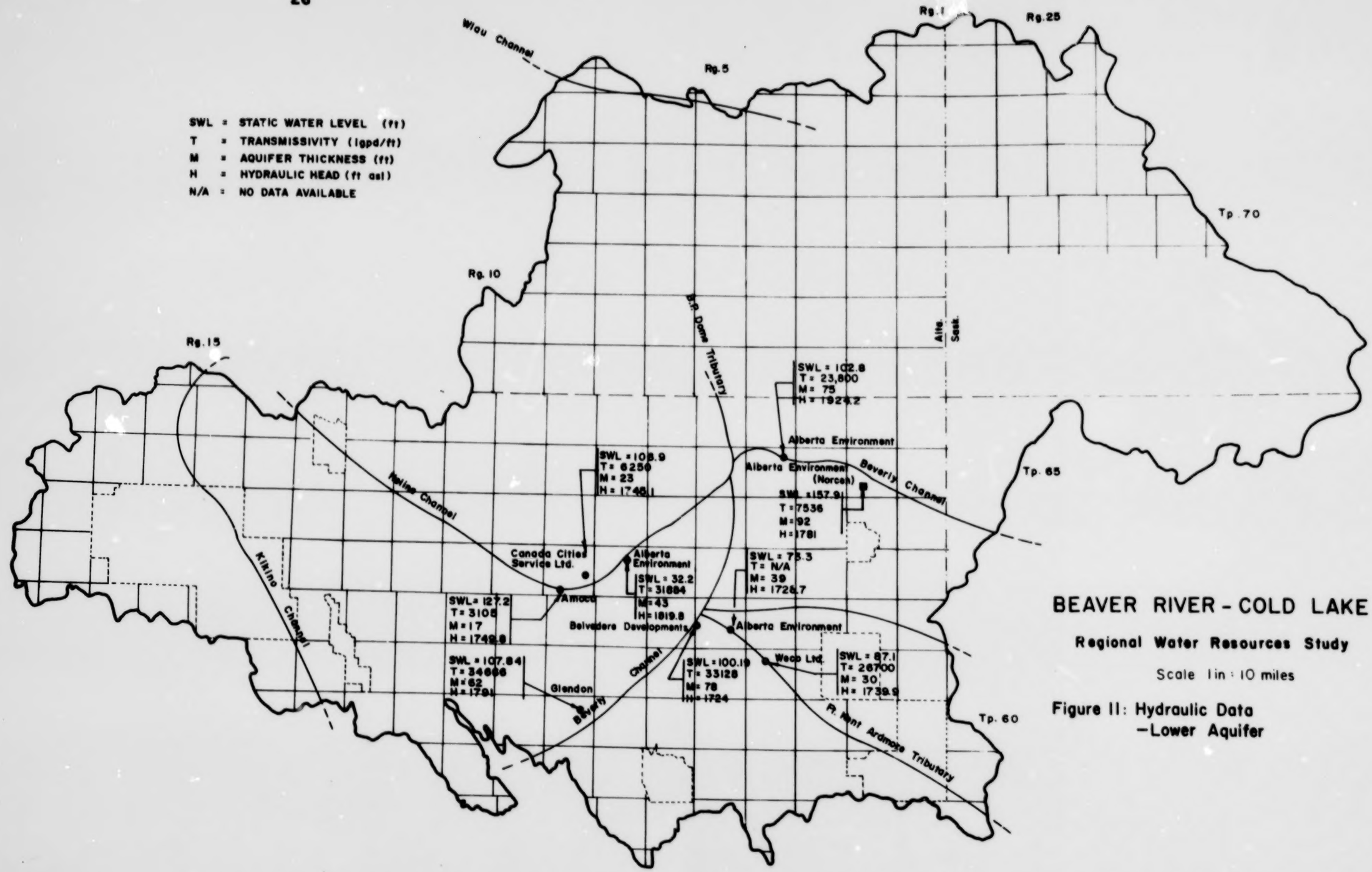
Examination of this data indicates that the direction of natural ground-water movement through both the Middle and Lower Aquifers is not well understood. In the Middle Aquifer (Figure 10), flow through the B.P. - Dome Tributary and the Beverly Channel is toward Cold Lake. Hydraulic head data in the Ft. Kent - Ardmore Tributary indicates ground-water flow is toward the Beverly Channel.

However, the direction of flow within the Beverly Channel is not known. The hydraulic head at the Alberta Environment Bonnyville observation well is approximately 528.5 metres (1734 feet), while at the Bourque Lake site, the hydraulic head is 595.5 metres (1954 feet). It is obvious that additional hydraulic head data for the Middle Aquifer in the Beverly Channel is required before the flow system can be defined.

TABLE 2

Results of Pumping Tests

Well Owner	Aquifer Tested	Transmissivity (m^2/day)	Aquifer Thickness (m)	Hydraulic Conductivity (m/day)
B.P.	Middle	174.26	10.06	17.3
Esso	Middle	155.55	22.86	6.8
Norcen	Middle	1,326.46	19.81	67.0
Alta. Env. (Norcen)	Middle	388.79	9.75	39.9
M.D. Bonnyville	Middle	298.08	14.33	20.8
Weco	Middle	245.92	20.12	12.2
Alta. Env. (Helina Chan.)	Middle	155.51	16.15	25.5
Dome	Middle	196.24	12.19	16.1
Alta. Env. (B.P. - Dome Tributary)	Middle	35.43	16.15	2.19
Amoco	Lower	46.28	5.18	8.9
Canada Cities Service	Lower	93.15	7.01	13.3
Weco	Lower	411.35	9.14	45.0
Belvedere Developments	Lower	493.74	23.77	20.8
Village of Glendon	Lower	516.66 (av)	18.90 (av)	27.3
Alta. Env. (Bourque Lake)	Lower	354.20	23.47	15.09
Alta. Env. (Norcen)	Lower	112.32	28.04	4.0
Alta. Env. (Helina Chan.)	Lower	475.20	16.15	36.3
Petro Canada	Lower Wiau Chan.	190.12	38.10	5.1



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Scale 1in : 10 miles

Figure 11: Hydraulic Data
—Lower Aquifer

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TABLE 3

Hydraulic Heads

Well Owner	Aquifer Screened	Hydraulic Head in metres above mean sea level
B.P.	Middle	636.12
Esso	Middle	598.63
Norcen	Middle	536.45
Alberta Envir. (Norcen)	Middle	543.46
M.D. Bonnyville	Middle	545.90
Weco	Middle	545.90
Dome	Middle	663.24
Alberta Envir. (Helina Channel)	Middle	556.26
Alberta Envir. (Bourque Lake)	Middle	592.84
Alberta Envir. (Ft. Kent)	Middle	528.52
Alberta Envir. (B.P. - Dome)	Middle	627.58
Amoco	Lower	533.40
Canada Cities Service	Lower	531.88
Weco	Lower	530.35
Belvedere Dev.	Lower	525.48
Village of Glendon	Lower	545.90
Alberta Envir. (Bourque Lake)	Lower	586.44

Table 3 ...

Well Owner	Aquifer Screened	Hydraulic Head in metres above mean sea level
Alberta Envir. (Ft. Kent)	Lower	527.00
Alberta Envir. (Norcen)	Lower	542.85
Alberta Envir. (Helina Channel)	Lower	554.74
Petro Canada	Wiau Channel	657.45

In the Lower Aquifer (Figure 11), the direction of flow is generally away from the area of Bourque Lake and the confluence of the B.P. - Dome Tributary with the Beverly Channel. At Bourque Lake, the hydraulic head in the Lower Aquifer is very high (586.5 metres or 1924.2 feet). The explanation for this is not readily apparent, although it may indicate that infiltration in this area is comparatively rapid, and that high hydraulic heads exist here as a result of interconnection between the Upper, Middle and Lower Aquifers. Such a model would serve to explain the observed potential for southwesterly flow of ground water in the Helina and Beverly Channels, away from Bourque Lake, without contradicting the observed potential for flow from Bourque Lake to the east, toward Cold Lake.

In addition to the lateral movement, there is the potential for a general downward movement of water from the Middle Aquifer to the Lower Aquifer over the entire study area. In fact, the discharge zones for both of the major aquifers have not yet been located.

Local ground-water flow systems are superimposed on the regional systems associated with the Middle and Lower Aquifers. These shallow local flow systems give rise to relatively fresh springs and flowing wells along river valleys and near lakes. Shallow aquifers modify these local flow systems.

3.3 Hydrochemistry

The typical mineralogic composition of tills in the Beaver River - Cold Lake area includes silicates (quartz, plagioclase, minor hornblend and pyroxene, the clay minerals illite, kaolinite, and montmorillonite), carbonates (calcite, dolomite), sulphates (gypsum, anhydrite) and

chlorides (halite, mirabilite). Because ground waters, in order to replenish the aquifers in the region, must percolate through the thick layers of glacial drift, their hydrochemistry may be expected to reflect the mineralogic composition of the drift.

Throughout much of the study area, carbonate and bicarbonate constitute over 60 per cent of the total ions on an equivalents-per-mil basis in all three aquifers (Ozoray, Wallick, and Lytviak, 1980). Sulphate constitutes more than 60 per cent of all anions over only a few very small areas throughout the region.

Of the cations, sodium plus potassium concentrations of greater than 60 per cent of total cations are found in small, isolated areas in the shallower aquifers, but become more common as one inspects the Middle and Lower Aquifers.

In all three aquifers: Upper, Middle, and Lower; the total dissolved solids concentrations are generally quite low, with concentrations below, or only slightly above 1000 mg/l. Exceptions to this are found in the southwest portion of the study area, in townships 63 through 65, ranges 11 through 13, where, according to Oxoray, Wallick, and Lytviak (1979), tds values greater than 2000 mg/l are found in the Upper Aquifer.

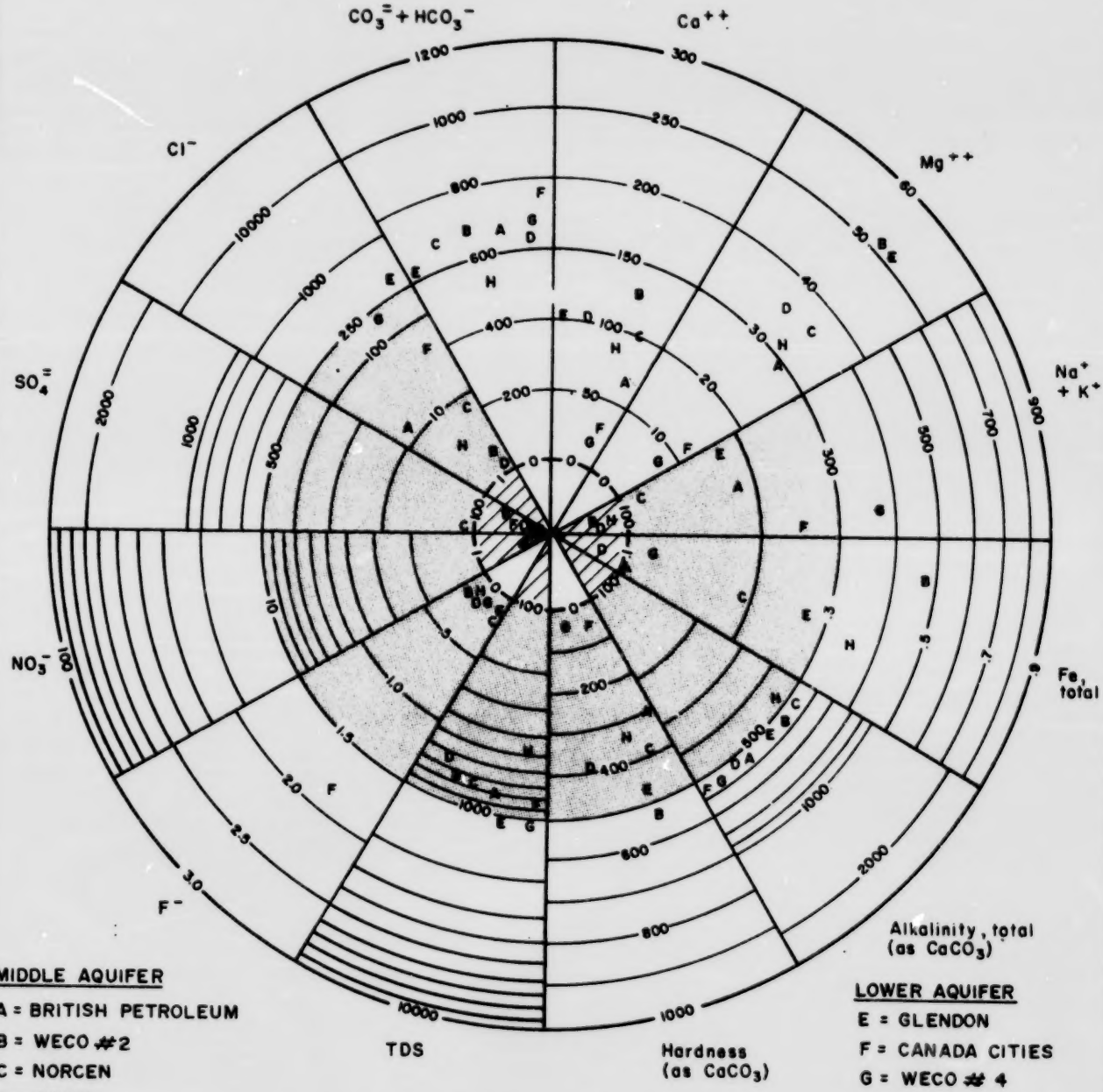
The ground waters in the Upper Aquifer are generally slightly saturated with respect to calcite and dolomite and undersaturated with respect to gypsum, illite, kaolinite, microcline, albite, and anorthite. The saturation index data suggest that calcite and clay minerals in the till, particularly calcium montmorillonite, are the controlling solid phases in the development of the shallow ground water chemistry (Ozoray, Wallick and Lytviak, 1979).

The chemical quality of ground waters from the Middle Aquifer is similar to that of the Upper. The waters are generally of good quality, and are suitable for municipal and steam injection purposes, with some treatment (Figure 12). Appendix A contains a summary of water analyses from both the Middle and Lower Aquifers. The ground waters from the Middle Aquifer are frequently high in iron, and are generally harder than those of the Lower Aquifer. The total dissolved solids concentration from the Middle and Lower Aquifers seldom exceeds 1000 mg/l. The waters are generally alkaline, with no apparent relationship between alkalinity and aquifer type. The noticeable constancy of the anion combination bicarbonate plus carbonate is due to saturation with respect to calcite.

Very generally, the concentration of the alkaline earth cations calcium and magnesium is higher in the Middle Aquifer than in the Lower. The alkali metal cations, sodium plus potassium, are more concentrated in the Lower Aquifer. This can be attributed to the tendency for ground waters assoicated with deeper, longer flow systems to evolve toward a sodium-rich chemical content, at the expense of calcium and magnesium. Calcium is taken up by cation exchange with clay particles, while sodium is released.

The Middle Aquifer, being rich in carbonate minerals, yields waters of a fairly constant concentration of carbonate plus bicarbonate. In waters from the Lower Aquifer, these concentrations are less constant from place to place, because the equilibrium has been changed by cation exchange.

Sulphate tends to be found in higher concentrations in the Middle Aquifer (generally less than 100 mg/l) than in the Lower, possibly due to the presence of gypsum and anhydrite in the sediments.



MIDDLE AQUIFER

A = BRITISH PETROLEUM
B = WECO #2
C = NORCEN
D = DOME

LOWER AQUIFER

E = GLENDON
F = CANADA CITIES
G = WECO # 4
H = BOURQUE LAKE

Within acceptable potable limits according to Canadian Drinking Water Standards and Objectives, 1968

Linear portion of scale (remainder is logarithmic)

Note All values shown are in ppm.

JOB No. B-171-12	WATER QUALITY IN SURROUNDING WELLS	DATE MARCH/82
SCALE		FIGURE 12

MLM Ground-Water Engineering

Iron concentrations in both the Middle and Lower Aquifers are quite high, with only two samples from the Middle Aquifer (Dome Petroleum's well, and Weco well #2) below the accepted potable limit of 0.3 mg/l as set forth by the Canadian Drinking Water Standards (1969).

Alkalinity is quite constant as a result of the constancy in the carbonate and bicarbonate content.

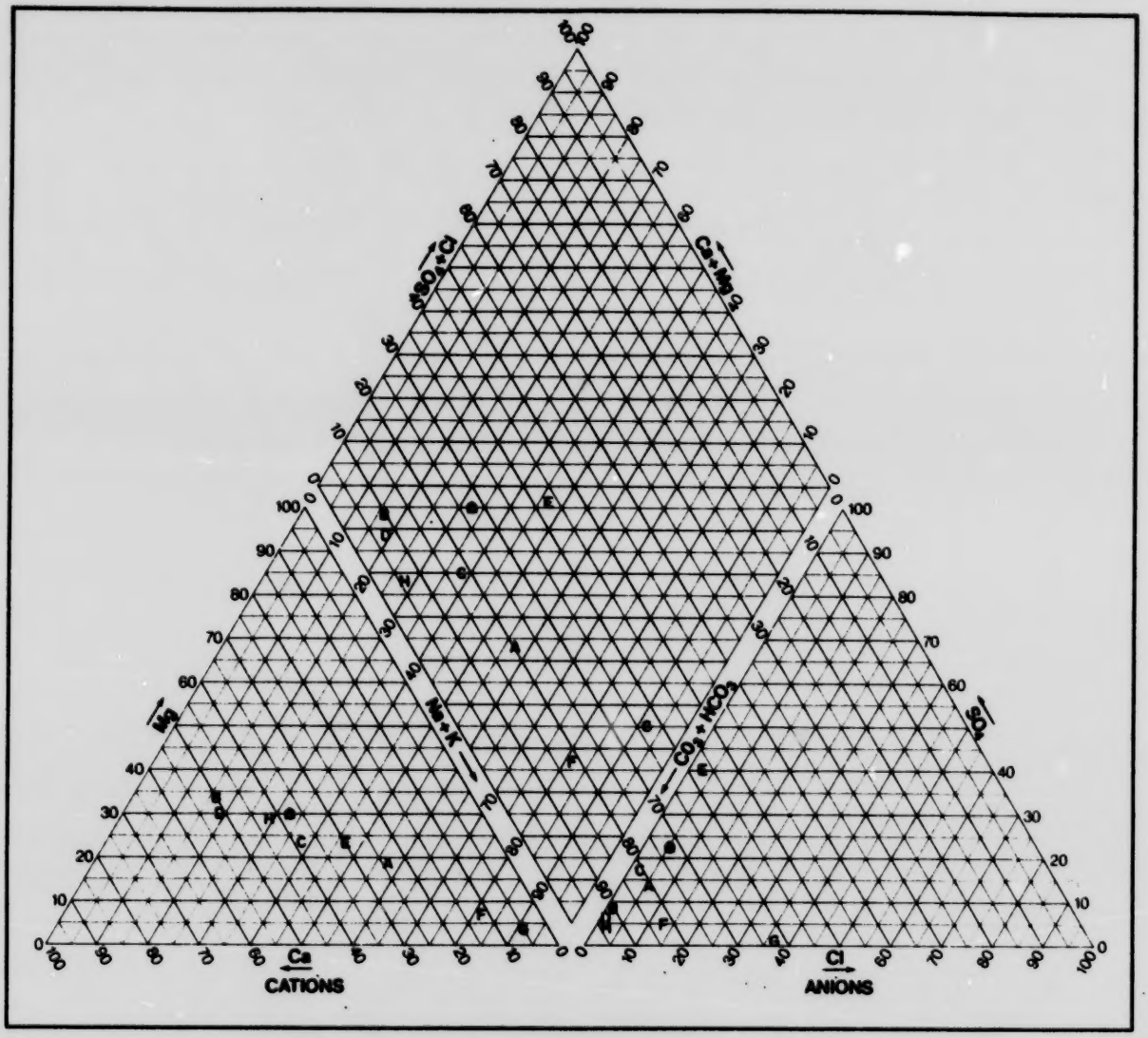
Chloride is variable, but in general, slightly more concentrated in the Lower Aquifer. This can probably be attributed to the release of some chloride into a solution from the Lea Park Formation of the Colorado Group, both of which are marine shales.

Fluoride concentrations are very constant throughout the Lower, Middle, and Upper Aquifers. This suggests that it is input very early in its journey through the ground water system, perhaps as it infiltrates through the upper tills. Because fluoride is a very conservative ion, no further changes in concentration are observed.

Nitrate and Nitrites are at very low concentrations in all locations sampled. This can be attributed to a very low natural nitrate content in the aquifer materials, and an unpolluted ground water regime.

From the accompanying Piper trilinear diagram, (Piper, 1944), on which are plotted several water samples from different locations within the Lower, Middle and Upper Aquifers, the following conclusions can be drawn:

a) There is a general tendency for ground waters moving downward from the level of the Middle Aquifer to that of the Lower Aquifer, to take up sodium and potassium, at the expense of calcium and to a lesser extent, magnesium.



MIDDLE AQUIFER
A = BRITISH PETROLEUM 97-66-S-4
B = WECO No. 2 5-25-61-4-4
C = NORCEN
D = DOME

UPPER AQUIFER
● = NW 28-61-4-4 (private well)

LOWER AQUIFER
E = GLENDON
F = CANADA-CITIES
G = WECO [illegible] 4
H = BOURQUE LAKE

Piper Trilinear Plot **Figure 13**

b) The Lower Aquifer is richer in dissolved chloride, probably because the ground waters come into contact with the marine shales of the bedrock.

c) No well-defined spatial relationship in the epm ratios of bicarbonate and sulphate can be seen.

d) As waters infiltrate deeper, they undergo a very general shift from calcium-magnesium bicarbonate to sodium-bicarbonate type.

4.0 GROUND-WATER SUPPLY POTENTIAL

4.1 Ground-Water Availability

4.1.1 Methodology

In order to determine the existing and potential significance of ground water as a supply source, it was necessary to devise a method to quantify the ground water resources of the region. The use of single well yields, particularly when they are few in number, is not satisfactory. Indeed, most of the aquifer tests conducted were at a rate far less than the calculated safe yield, which casts some doubt on their validity. There are also cases where ground-water withdrawals have had to be restricted as ground-water mining occurred at pumping rates far less than the theoretical safe single well yield.

For this study, we have attempted, where sufficient data is available, to calculate the natural ground-water flow-through for the two major aquifers using the following form of Darcy's Law:

$$Q = 0.365\ K\ I\ A$$

where: Q = flow rate in dam^3/year
K = hydraulic conductivity in m/day
I = hydraulic gradient in m/m
A = crossectional area of the aquifer in m^2

The values of hydraulic conductivity and hydraulic heads were obtained from the aquifer tests conducted in the two aquifers. Crossections were prepared of the aquifers where hydraulic data was available, and the aquifer areas were calculated from them. The location of the crossections are shown in Figure 4 (pocket). This flow rate represents the volume of water that moves through the aquifer under natural conditions. Ground water can be removed from an aquifer up to this natural flow without removing water from storage and depleting the aquifer.

Therefore, a comparison of the current and potential ground-water demands to the natural ground-water flow-through will identify areas where supplies may be adequate and areas where ground-water mining may occur. This method has its limitations in that it does not consider leakage from overlying formations. That is, it more or less treats the aquifers as two pipelines. We feel that this method does provide a good first approximation of the regional ground-water resources, and that areas of potential problems can be identified. In this way, future data collection requirements can be determined. However, the flow values calculated should be taken as qualitative due to the limited data.

4.1.2 Middle Aquifer

The calculations of natural ground-water flow in the Middle Aquifer are given in Table 4. The

TABLE 4

Ground-Water Availability
Middle Aquifer

Channel Reach	A (m^2)	I (m/m)	K (m/day)	Flow m^3/day	Flow dam^3/yr
Beverly Channel at Fort Kent	7.40×10^4	2.28×10^{-3}	20.8	2,770	1,010
Helina Channel	1.18×10^5	2.77×10^{-3}	13.8	4,526	1,652
Beverly Tributary at B.P.	1.24×10^5	1.52×10^{-3}	7.99	1,505	549
Beverly Channel at Norcen	1.24×10^5	2.70×10^{-3}	53.3 (av)	17,800	6,500

value of natural ground water flow at the Norcen site will represent the total flow in the Beverly Channel east of the B.P. - Dome Tributary.

Ground-water flow through the B.P. - Dome Tributary was calculated between B.P. (LSD9-Sec7-Tp66-Rge5-W4M) and the Alberta Environment observation well (SW¼-Sec28-Tp65-Rge5-W4M). An average value of hydraulic conductivity was used and a flow-through of 549 dam^3/year was obtained.

Calculations made between Alberta Environment wells at the B.P. - Dome Tributary and the Helina Channel (SW¼-Sec27-Tp73-Rge7-W4M) indicated a flow-through of 1652 dam^3/year to the south-west along the Helina Channel. This flow may include part of the flow down the B.P. - Dome Tributary.

4.1.3 Lower Aquifer

Calculations of natural ground-water flow through the Lower Aquifer over the various bedrock channel reaches are summarized in Table 5.

Examination of Table 5 shows that in the Beverly Channel, between Glendon and the Belvedere Developments well, near the confluence of the Ft. Kent - Ardmore Tributary, there is a flow of 412 dam^3/year, to the north.

Flow in the Fort Kent - Ardmore Tributary is toward the Beverly Channel, and is calculated to be approximately 933 dam^3/year.

Flow through the Helina Channel also presents a seeming paradox. Between Amoco (LSD7-Sec4-Tp63-Rge8-W4M) the ground water flow is indicated to be toward Cold Lake, at 87.6 dam^3/year. The Lower Aquifer here is thin (approximately 7 metres thick) and the hydraulic conductivity is the lowest for this aquifer than anywhere else in the region.

TABLE 5

Ground-Water Availability
Lower Aquifer

Channel Reach	A (m^2)	I (m/m)	K (m/day)	Flow m^3/day	Flow dam^3/yr
Beverly Channel Near Confluence of Fort Kent Tributary	7.91×10^4	7.05×10^{-4}	20.8	1,130	412
Beverly Tributary at Fort Kent	1.61×10^5	3.50×10^{-4}	45.0	2,560	933
Helina Channel (between SW¼-Sec27-Tp63-Rge7-W4M and Amoco)	9.90×10^4	1.66×10^{-3}	11.1	1,673	611
Beverly Channel Tributary at B.P.	- No Lower Aquifer -				
Beverly Channel at Norcen	3.19×10^5	2.49×10^{-3}	4.0	3,191	1,165

Between the Alberta Environment well (SW¼-Sec27-Tp63-Rge7-W4M) and Amoco, however, the flow is calculated to be to the south-west, at a volume of 611 dam^3/year. The latter of these estimates is probably the most reliable, as the head drop between these two wells is large (21.34 metres, or 70 feet), and not likely to be reversed by the error in estimating ground surface elevation from NTS Series maps. The head drop between Amoco and Canada Cities Service is very low (1.3 metres, or 4 feet), and could easily be reversed within the above-noted topographical error.

Calculations made between Alberta Environment's wells at Bourque Lake (LSD4-Sec26-Tp65-Rge5-W4M) and Norcen (SW¼-Sec9-Tp65-Rge2-W4M) yielded a natural flow-through of approximately 1165 dam^3/year. This value represents the total flow through the Lower Aquifer in this portion of the Beverly Channel.

4.1.4 Wiau Channel

To date, very little hydraulic data is available for the two aquifers present in the Wiau Channel. Therefore, it was not possible to calculate natural flow rates through these aquifers. However the results of the test drilling and pump testing conducted by Alberta Environment in the Wiau Channel (10-29-73-7-4) indicate that significant supplies of ground-water can be obtained.

The aquifer testing indicated that the lower sand aquifer had a hydraulic conductivity value of 5.1 m/day, and a single well yield of in the order of 3394 m^3/day (519 Igpm).

4.2 Ground-Water Demands

The ground-water demands for the study area have been prepared for the various time horizons by MacLaren Plansearch. This report breaks down the ground-water demands into three major types of users. They are: rural domestic, municipal and industrial users.

The bulk of the rural domestic water supplies in the study area are obtained from individual wells completed in the lensitic sands that make up the Upper Aquifer. As this aquifer was not extensively studied, only the municipal and industrial demands are used to determine the adequacy of ground-water supply. A summary of the municipal and industrial ground-water demands for the various bedrock channel reaches and time horizons is presented in Table 6.

Examination of these data indicates that between 1985 and 2000 there will be an increase in ground-water demands. However, in the year 2000, for the high development scenario, a number of the oil companies plan to switch to surface water. The companies that plan this switch are Union Texas, Dome Petroleum, Norcen, and Husky Oil. The projected ground-water demands for the year 2015 are less than the previous time horizon. This is primarily due to the completion of the Canada Cities plant in the low development scenario and the completion of the Amoco plant in the high development scenario.

4.3 Adequacy of Ground-Water Supply

It is expected that the Middle and Lower Aquifers would be heavily utilized by the municipal and industrial sectors, in any water usage scenario. Ground-water flow calculations have indicated that there is a substantial flow-through in each of these aquifers, as shown in Tables 4 and 5.

TABLE 6

Municipal and Industrial
Ground-Water Demands

Channel Reach	User	Withdrawals (dam^3/year) 1985 High	1985 Low	2000 High	2000 Low	2015 High	2015 Low
Helina Channel	Amoco Canada	1,160	--	2,320	--	--	--
	Canada Cities Services	410	--	750	410	750	--
Beverly Channel Upstream of Sec20-63-5-4	Village of Glendon	80	70	200	120	270	210
	Belvedere Dev.	?	?	?	?	?	?
Ft. Kent - Ardmore Tributary	Fort Kent - Ardmore	60	60	180	100	240	170
	Union Texas	180	130	--	130	--	130
B.P. - Dome Tributary	B.P. Canada	2,190	1,100	2,190	2,190	2,190	2,190
	Dome Petroleum	830	690	--	--	--	--
Beverly Channel	Norcen Energy Resources	140	140	--	460	--	460
	Husky Oil (Alberta)	165	--	--	--	--	--
	TOTALS	5,215	2,190	5,640	3,410	3,450	3,160

Based upon the information gathered to date, the following comments are made as to the adequacy of ground-water supplies:

a) It appears the large ground-water demands in the Helina Channel (Amoco and Canada Cities) may not be obtained from the Middle and Lower Aquifers. The maximum demand of 3070 dam^3/year (year 2000; high production) is in excess of the combined flow of 2263 dam^3/year.

b) In the Beverly Channel south of Sec20-Tp63-Rge5-W4M, the only user of ground-water is the Village of Glendon. The maximum projected demand of 270 dam^3/year is much less than the natural flow through the Lower Aquifer of 412 dam^3/year in this part of the channel, which lies between Glendon, and the confluence of the Beverly Channel and the Ft. Kent - Ardmore Tributary.

c) Ground-water demands in the Fort Kent - Ardmore Tributary of the Beverly Channel are estimated to be 240 dam^3/year in 1985. The users are Fort Kent - Ardmore, and Union Texas. Worldwide Energy plans to use waste water from Bonnyville. As the combined flow through this channel is approximately 1943 dam^3/year, no problems are envisioned in meeting these demands.

It may be feasible for Union Texas to obtain their high development water demands of 730 dam^3/year from ground-water rather than surface water. This would require a relocation of their well field to an area centrally located in the channel. If this was done, then the maximum ground-water demand in 2015 would be 970 dam^3/year, which is still less than the natural flow through the channel.

d) In the B.P. - Dome Tributary of the Beverly Channel, the potential ground-water demand in 1985 is estimated to be between 1790 and 3020 dam^3/year. This demand will decrease to 2190 dam^3/year in 2000, as current scenarios show Dome switching to surface water. Existing data indicates a natural flow of 549 dam^3/year, although it should be stated that the geologic relationships in the channel are not well understood.

e) In the remainder of the Beverly Channel, two oil sands plants are located. These are Norcen and Huskey Oil. In 1985, the ground-water demands are projected to be from 140 to 205 dam^3/year. In 2000, the ground-water demand is 460 dam^3/year for the low development scenario. The high development scenario has both oil companies utilizing surface water. The ground-water resources are capable of meeting the projected demands. It is likely that Norcen could use ground water for its high development scenario (1740 dam^3/year) as the Middle Aquifer at Norcen's location is extremely productive (6500 dam^3/year).

5.0 GROUND WATER - SURFACE WATER INTERACTION

One of the terms of reference of this study called for an accounting of ground water - surface water interaction, where the data is adequate and the interaction is critical to the surface water supply balance. In general, all ground water originates as surface water with the principal sources of natural recharge being precipitation and infiltration. Water enters water-bearing formations (aquifers), which then act as conduits for transmission and reservoirs for storage of ground water. This water travels slowly for varying distances until it returns to the surface by the action of natural flow. Ground water emerging into surface stream channels aids in sustaining streamflow when surface water input is low or non-existent.

As previously discussed in the section on natural ground-water flow, there is a shallow surficial flow system associated with the Upper Aquifer. This system is superimposed on the more regional flow systems of the Middle and Lower Aquifers. It is likely this shallow flow system discharges in places into surface water bodies. However, because of the limited data and relative unimportance of the Upper Aquifer, this flow system was not studied extensively.

Hydraulic head data available to date for the Middle and Lower Aquifers indicate that the vertical component of ground-water flow is downward. In fact, discharge areas for these aquifers have not yet been identified. This information, combined with the fact that the piezometric surface for these aquifers is below the level of most surface water bodies, indicates that these aquifers do not interact with surface water bodies. One exception is that the Middle Aquifer, and possibly the Lower Aquifer, may discharge into Cold Lake.

If increased utilization of ground water from the Middle and Lower Aquifers occurs in excess of the natural flow rates calculated in Section 4.2, an increase in the vertical hydraulic gradient may occur. This would result in increased leakage from the Upper Aquifer zones to the major aquifers below, which over the long term, could alter the shallow ground-water flow system. The increase in rural domestic use as predicted in the MacLaren Plansearch Report (3790 - 4300 dam^3/year in 2015) would also alter existing shallow flow systems.

Recharge areas would likely expand, causing a reduction in surface water runoff. The size of discharge areas and the volume of ground-water discharge from the shallow system would also be reduced, which would in turn, alter the base flow components of streams and rivers.

It is impossible at this time to quantify this interaction because of insufficient data.

6.0 CONCLUSIONS

Based upon the findings of this study, the following conclusions are warranted:

a) The major aquifers within the study area that are capable of meeting municipal and industrial demands are the sand, sand and gravel, and gravel units associated with the preglacial bedrock channels. Two of these units have been found to be continuous over the study area, and have been called the Lower and Middle Aquifers in this report. The Lower Aquifer, in general, directly overlies the bedrock surface and is restricted to the bedrock channels. The Middle Aquifer is an intertill unit that tends to overlap the bedrock valley sides.

b) The recently identified Wiau Channel, the bulk of which is outside the study area, contains two major sand units of large areal extent. This valley has not yet been extensively studied.

c) The natural ground-water flow in the Lower and Middle Aquifer is not totally understood due to the limited data. The direction of flow in the Beverly Channel between the Fort Kent - Ardmore Tributary and Bourque Lake is not known. Flow in the Helina Channel is suspected to be in a southwesterly direction.

d) The water quality in both the Lower and Middle Aquifers is good, meeting most of the objectives set forth in the Canadian Drinking Water Standards. The one water sample from the Wiau Channel also exhibits good quality.

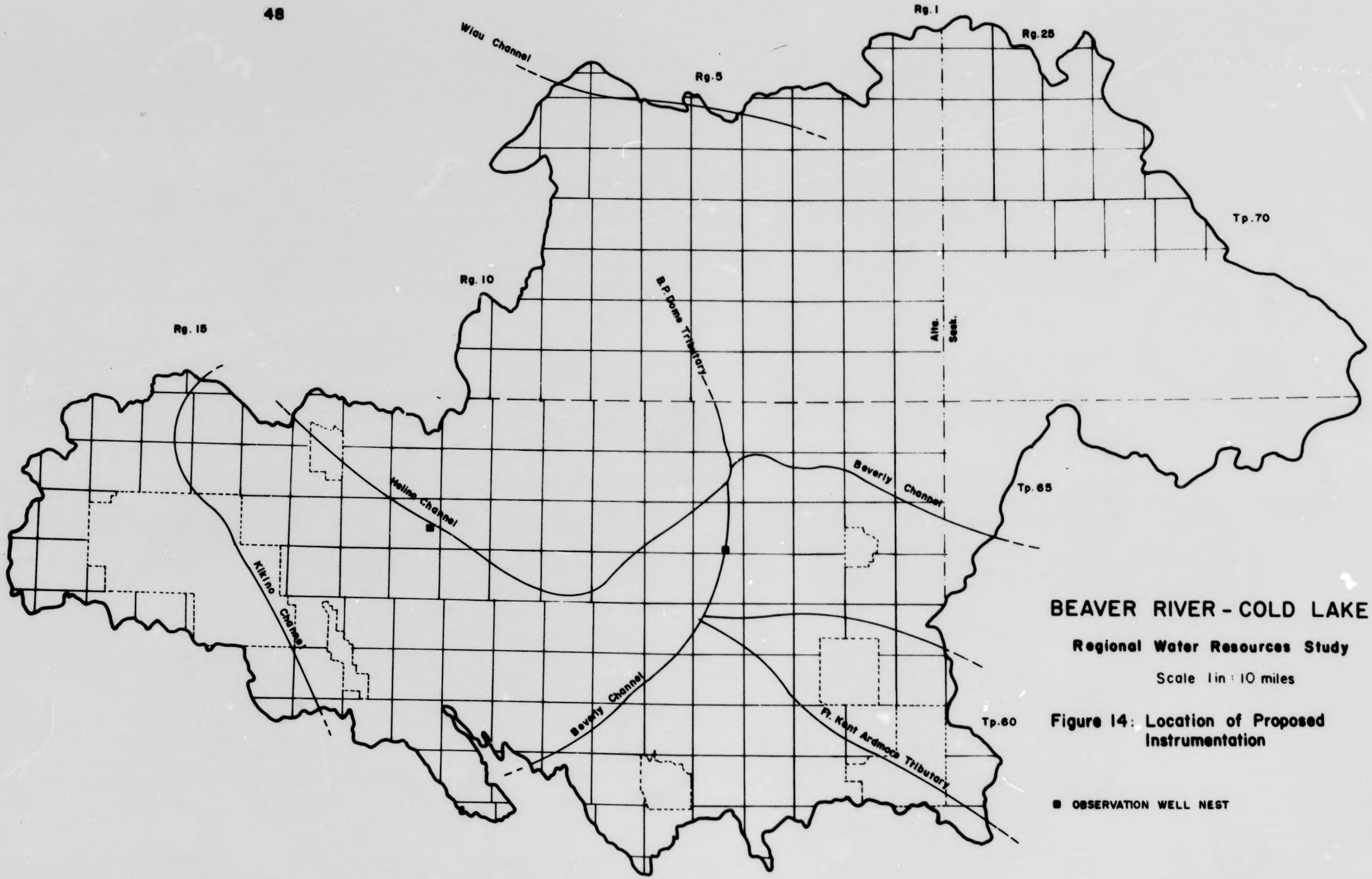
e) Review of the water demand scenarios indicates that regionally there are sufficient ground-water resources to meet the projected demands without causing depletion. However, locally there may be problems in meeting the demands. The most notable of these are: the Helina Channel at Amoco and Canada Cities, and the B.P. - Dome Tributary.

f) The exact interaction between ground water and surface water cannot be quantified at this time. It is felt the shallow ground water flow system associated with the Upper Aquifer, discharges into surface water bodies in the study area. The more regional flow systems associated with the Lower and Middle Aquifers does not appear to directly interact with surface water bodies, although the very high hydraulic heads at Bourque Lake, and within the B.P. - Dome Tributary may be an indication of ground-water recharge. Utilization of the Lower and Middle Aquifers above the natural flow rates could alter the shallow flow system. Also, increased utilization of the Upper Aquifer for rural domestic purposes as predicted in the MacLaren Plansearch Report, could further alter this system.

7.0 RECOMMENDATIONS

This study has identified problems in determining the regional flow system. It is important to have a good understanding of the flow system to determine the ground-water resources of the study. Because of this it is recommended that the following work be undertaken (Figure 14):

a) An observation well nest be placed in the Beverly Channel between the confluence of the Fort Kent - Ardmore Tributary and the confluence of the Helina Channel. This nest will provide data as to the direction of ground-water flow in this part of the channel.



BEAVER RIVER - COLD LAKE

Regional Water Resources Study

Scale 1 in : 10 miles

Figure 14: Location of Proposed Instrumentation

■ OBSERVATION WELL NEST

M L M GROUND-WATER ENGINEERING

b) An observation well nest be placed in the Helina Channel northwest of the Amoco site. This nest is necessary to verify the direction of natural flow in the Helina Channel. Because of the potential for ground-water utilization in the Helina Channel, this information is necessary.

As previously stated, the use of Darcy's Law to determine the regional ground-water resources is a simplification. Add to this the problems in ascertaining the natural flow direction in some area and one realizes the calculated values can only be used qualitatively. It is recommended that future data aquisition be geared to ultimately establish a three-dimensional computer model of the study area. Because of the complexity of the aquifer distribution and boundary conditions, this is the only method to quantify the impact of the various water demand scenarios.

The model can take into account the aquifer's areal distribution, variation in hydraulic parameters, leakage between aquifers, and recharge. Simulations of the various water demand scenarios will determine if the ground-water mining will occur and if so, if the resulting lowering of water levels is acceptable.

Once the model is established, then various scenarios can be run. Because of this, the model is an invaluable management tool for the quantifying and allocating of ground-water resources.

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Respectfully submitted,

MLM GROUND-WATER ENGINEERING

M. G. Mateyk, P. Geol.,
Project Hydrogeologist

APPENDIX A

Summary of
Water Quality Analyses

Determination	Canada Cities 6-13-63-8-4	B.P. 9-7-66-5-4	Weco #2 5-25-61-4-4	Weco #4 3-28-61-4-4	Weco 5-28-61-4-4	M.D. Bonnyville SE32-61-4-4	Norcen 12-24-65-2-4
pH	8.2	7.5	7.1	8.38	7.10	--	7.8
TDS	896	796	726	1006	696	914	735
Sodium	245	180	46	376	49	204	112
Potassium	4.1			8		--	--
Calcium	30	68	127	18	120	--	100
Magnesium	12	29	51	8	50	--	36
Carbonate	Nil	Nil	Nil	20	Nil	--	Nil
Bicarbonate	684	670	690	680	662	--	636
Alkalinity	561	550	566	592	543	--	522
Sulphate	44	88	55	4	60	--	103
Chloride	47	28	3	225	5	30	9
Hardness	125	287	526	78	506	370	398
Iron	1.78	0.10	4.71	1.18	3.65	2.0	1.95
Fluoride	--	--	0.21	0.15	0.24	--	0.19
Nitrate	<0.02	< 1	< 0.5	< 1	< 0.5	--	< 0.10
Spec. Cond.							
Aquifer Type	Lower Aquifer	Middle Aquifer	Middle Aquifer				Middle Aquifer

Determination Determination	Bourque Lake Observ. Well 4-26-65-4-4	Private Well NW28-61-4-4	Dome (PW1-81) NE5-67-4W4	Village of Glendon (PW-1)
pH	7.9	7.9	7.73	7.8
TDS	481	947	617	1005
Sodium	63	123	43	173
Potassium	4.2	9	3.4	5.7
Calcium	82	140	101	102
Magnesium	32	62	35.7	50
Carbonate	Nil	Nil	Nil	Nil
Bicarbonate	548	780	614	636
Alkalinity	449	639	503	522
Sulphate	23	194	30.5	341
Chloride	6	31	1.2	21
Hardness	338	600	399.5	460
Iron	3.48	0.4	0.06	2.72
Fluoride	0.14	0.18	0.19	0.21
Nitrate	< 0.10	< 0.45	0.003	< 0.05
Spec. Cond.		1500	913	1569
Aquifer Type	Lower Aquifer	Upper Aquifer	Middle Aquifer	Lower Aquifer

APPENDIX C

GROUND WATER MODELLING

A Report Prepared By
C. GOLD AND T. CHAU
EARTH SCIENCES DIVISION
ALBERTA ENVIRONMENT

Alberta MEMORANDUM

ENVIRONMENT EARTH SCIENCES DIVISION

FROM L.D.M. Sadler
Director
Earth Sciences Division

OUR FILE REFERENCE

YOUR FILE REFERENCE

TO Carl Primus
Director
Planning Division

DATE 1983 08 24

TELEPHONE

SUBJECT Groundwater Study: Cold Lake - Beaver River Basin

We are pleased to submit the final report which provides the groundwater resources evaluation for the Cold Lake - Beaver River Basin. The report, entitled "A Modelling Study of Groundwater Allocation in the Cold Lake - Beaver River Basin", will be included as an appendix in the water management report prepared by your division.

Please contact our division with any questions pertaining to this study.

L.D.M. Sadler
Director
Earth Sciences Division

tsc/kc

Encl.

ABSTRACT

A mathematical modelling study was conducted in the Cold Lake-Beaver River Basin to evaluate the groundwater supply potential of two major aquifers in the Empress and Durlingville Formations. Although there is a relatively large amount of geological information available for the study area (about 14,200 km^2), there is a limited hydrogeological data base. Calibration of a two dimensional, finite element aquifer flow model was carried out on each aquifer by comparing simulated piezometric heads with observed water levels for 1980. Aquifer recharge was estimated and areas of data deficiency were identified in this phase of model calibration. Recharge determined for the Durlingville Aquifer was substantially higher than the Empress Aquifer. A sensitivity study was also performed to assess the effect of parameter variations on the hydraulic head distribution in the Empress Aquifer. The model was then used to predict the hydrological impact on each aquifer with several water demand schemes. A long term feasible groundwater withdrawal scheme for potential users was developed for each formation. The Durlingville Aquifer was shown to have better groundwater allocation potential than the Empress Aquifer.

ACKNOWLEDGEMENTS

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Chapter 1

INTRODUCTION

The Planning Division of Alberta Environment, in view of the rapid growth in water demands in the Cold Lake-Beaver River Basin, has undertaken a water management study for the region. Short and long term plans are being formulated to manage the basin's surface water and groundwater resources. The main objective of the proposed management plan is to ensure adequacy of water supply to meet future demands of users in the region. To attain this objective, regional studies of the basin's surface water and groundwater supply potential are required. In recent years, the Earth Sciences Division of Alberta Environment started a program to obtain the surficial and bedrock stratigraphy of buried channels in East-Central Alberta (Yoon and Vander Pluym, 1974; Gold, 1979). The purpose of this program is to delineate a regional hydrogeologic framework on which an assessment of the basin's groundwater supply potential can be made using a mathematical model. The model, with an adequate data base for input and verification, is an useful tool to analyze the sensitivity of the aquifer system to various proposed water management alternatives. The specific management scheme which maximizes the use of the total available groundwater resources of the aquifer system will be incorporated by the river basin planners into a long term water management plan.

A finite element aquifer flow model was used to obtain quantitative assessments of the groundwater supply potential of two major aquifers (Empress and Durlingville Aquifers) in the basin. The Empress Aquifer, found in the Empress Formation, is the lowermost of the multilayered, surficial aquifer systems in the basin. Underlain by the bedrock, it is seperated from the overlying Durlingville Formation by the Bronson Lake till. Previous groundwater resource evaluations using analytical or numerical models were conducted on a local scale (e.g. Baydack and Render, 1981; Hydrogeological Consultants Ltd., 1976). This report presents the first regional groundwater modelling study for the basin.

1.1 Purpose of Study

The purposes of this study are:

(1) To synthesize and interpret available hydrogeologic data and construct the data base as necessary for model input,

(2) To calibrate the model by comparing computed responses with observations and examining the adequacy of the data base along with calibration results,

(3) To perform a sensitivity study of aquifer responses to model parameter variations,

(4) To use the predictive capability of the model to identify a feasible groundwater withdrawal scheme for potential water users in each aquifer system,

(5) To make recommendations for future study based on modelling results obtained from this investigation.

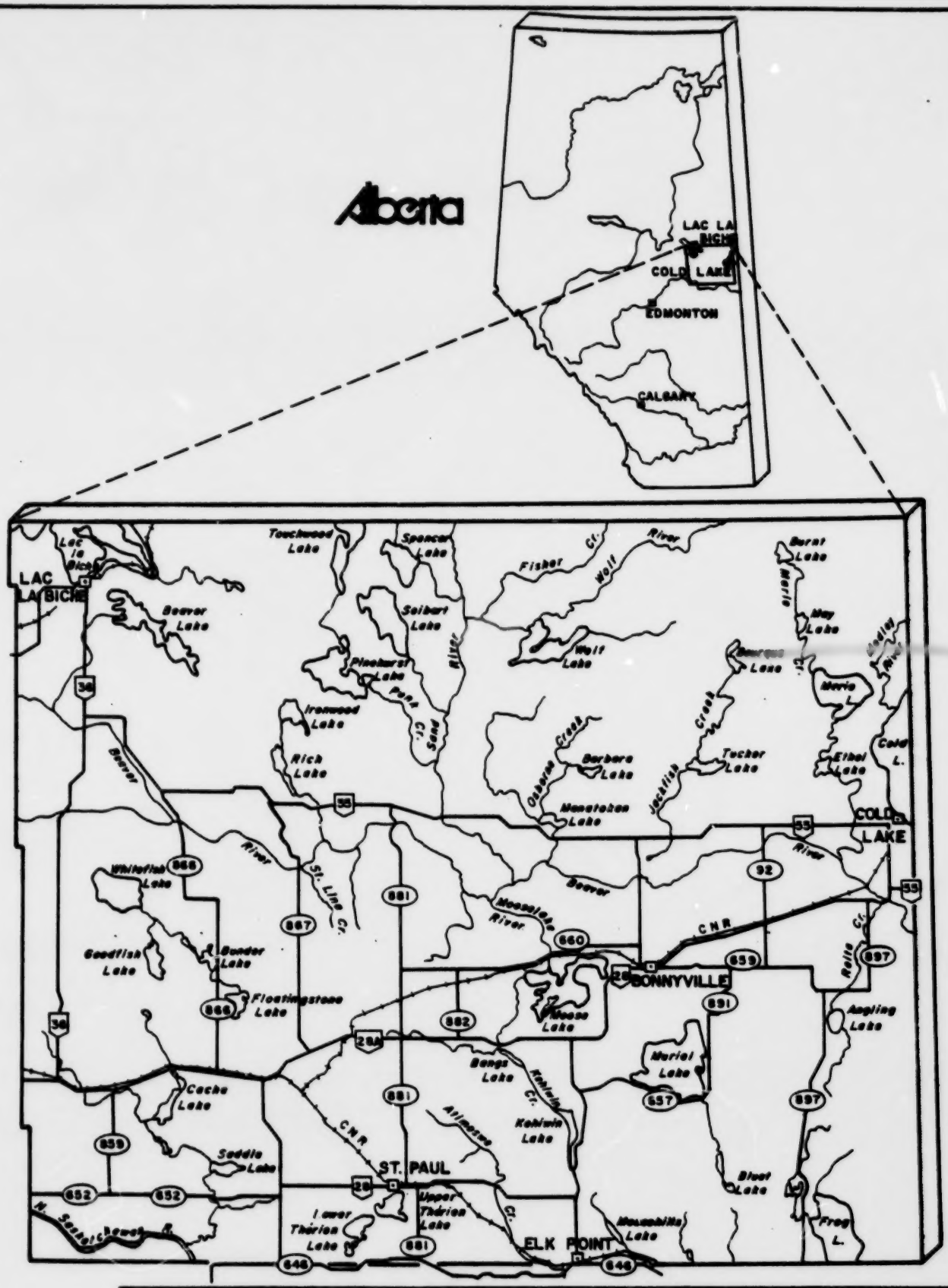
1.2 Location of Study Area

The location plan of the study area is given in figure 1.1. The study area, about 14,200 square kilometres, lies between longitudes 110° and 112° west and latitudes 54° and 55° north. It covers parts of townships 58 to 69, within ranges 1 to 14, west of the fourth meridian. The area was chosen to include present and anticipated future groundwater users in the basin.

1.3 Investigational Procedure

The study was conducted in several phases:

(1) Geological data were collected and interpreted to produce maps and cross-sections in the study area. The maps show locations of wells containing pertinent information on the surficial geology in the area - an estimated 2000 data points selected from a variety of water well industry, oil and gas industry, and other government sources. Also indicated on the maps are depths to the Cretaceous



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bedrock surface and interpreted contours of the preglacial topography indicating the main channels of the preglacial or interglacial drainage system. Cross-sections were constructed along each township line and range line and appropriate well logs selected to indicate the surficial and bedrock stratigraphy. These maps and cross-sections covered much of the area from Tp 55 to Tp 74, R 1 to R 18. In addition, numerous cross-sections were constructed along and across the thalwegs of the channels in order to delineate aquifer boundaries. The maps and cross-sections provided a general picture of the areal extent of the two major aquifers and the stratigraphy of the multiaquifer systems. A separate geological report, currently under preparation by Gold, will contain the maps and cross-sections for the study area.

(2) Through the Groundwater Resources Information Service of the Hydrogeology Branch, a computer search was conducted to locate wells within the study area. Wells tapping the Empress and Durlingville Aquifers were identified and the reliability of static water levels at these wells was assessed. More detailed and site specific hydrogeologic data for pumping centers were obtained from the Ground Water Rights Branch. Information on hydraulic properties, water level history at pumping and observation wells, and magnitude of pumpage at these locations was collected and interpreted. Additional observation wells were installed by the Earth Sciences Division at key locations in the basin in an attempt to clarify general flow direction in the aquifer system. Aquifer tests were also conducted with these wells to determine hydraulic parameters.

(3) Having completed the data identification phase, the data base for model input was constructed from available hydrogeologic data. This required specification of aquifer properties, aquifer stresses and boundary conditions over the finite element mesh which represents the aquifer domain. Model application started with calibration of the flow model, a process by which different model

input parameters were verified or determined. It involved choosing a period in the past (1980) for which data were available on the excitation (pumpage and recharge) and response (water level) behaviour of the aquifer. With this excitation as input, the model response for this period was compared with water levels recorded at an observation well.

(4) Having established confidence in model input parameters during the calibration phase, the model was used to predict the steady state response of the aquifer subject to various groundwater withdrawal schemes. A feasible withdrawal scheme was identified for each individual aquifer.

Chapter 2

GEOLOGICAL SETTING OF THE STUDY AREA

2.1 Bedrock Geology

The Western Canada sedimentary basin is a gently dipping trough between the Cambrian Shield in the northeast of Alberta and mountain ranges to the southwest. This basin has been a shallow marine sea in two geological periods: the Devonian and the Cretaceous. At the start of Cretaceous time, a shallow sea existed between the Canadian Shield and the central Cordilleran mountains. The general history of Cretaceous deposition is the history of advancing and retreating marine episodes. These are preserved in the existing rock types. A shale formation is the result of a marine advance and the subsequent deposition of fine grained clastic materials (mostly clays) at some distance from the sediment source. The various sandstone wedges which separate these shales throughout much of the province are the result of marine retreat and the development of extensive deltaic deposits along the shorelines of the time. These sand wedges extend outward into the centre of the basin, their extent depending on the extent of marine regression and the amount of available sand size sediment from the high ground to the southwest and, to a lesser extent, to the northeast. The main geological map units of the Cretaceous period found within the study area are:

(1) The Lower Mannville, which is primarily a continental sandstone immediately overlying Devonian rocks that had been eroded extensively during a long time period.

(2) The Upper Mannville, which represents a time of marine transgression over the non-marine beds below. It is somewhat mixed in composition and not simple in structure as it consists of both marine shales and non-marine sandstones. In northern and central Alberta, it becomes more shaly in composition.

(3) The Lower Colorado, which represents a time of complete marine inundation and is almost entirely composed of shale. Within the Lower Colorado unit the Joli Fou Formation and the Viking Formation are found. The Joli Fou is a thin marine shale. The Viking is a thin fine grained sandstone.

(4) The Upper Colorado Group, also consisting of relatively uniform dark gray shale. Within it are found the Fish Scales marker and also the First and Second White Specks marker horizons.

(5) The post-Colorado formations in Alberta, which can be simplified to consist of the Lea Park shale followed by the Belly River sandstone and then the Bearpaw shale. Overlying the Bearpaw shale is the Horseshoe Canyon Formation, again primarily sandstone.

Within the study area, the Cretaceous bedrock immediately underlying the surficial deposits is primarily the Lea Park shale. In the extreme southwest, however, the Belly River sandstone may also occur, overlying the Lea Park shale. All Cretaceous formations in this area dip gently to the southwest.

Following the retreat of the last Cretaceous sea in Alberta, the Bearpaw sea, deposition of the continental sandstones of the Cretaceous Horseshoe Canyon and the Tertiary Paskapoo, all of which are to the southwest of the study area, was followed by a long period of continental erosion in which many of the uppermost Cretaceous sediments were removed. In northern Alberta, the combined Belly River sandstone and Horseshoe Canyon Formation are termed the Wapiti Formation as the intermediate Bearpaw shale is absent. It is probable that the Belly River or Wapiti Formation at one time existed throughout the study area, but they have subsequently been removed by erosion, exposing the underlying Lea Park shale.

2.2 Bedrock Topography and Buried Valleys

Gold et al. (1983) prepared a bedrock topography map for the study area. A similar map (in pocket) indicates several channels incised into the uppermost Cretaceous Lea Park shale. The largest of these, the Helina Valley, extends westward from Saskatchewan through Cold Lake and Marie Lake, swings southwest near Marguerite Lake, passes beneath Manatokan Lake and then swings to the northwest towards Lac La Biche. It is interpreted that this valley formed part of a southeast collector for drainage emanating from the Rockies to the southwest. The second major channel, the Beverly, extends from Marguerite Lake south to Moose Lake and southwest and west through Vincent Lake and Cache Lake in the southwest of the study area. This valley once formed the channel of the preglacial North Saskatchewan River. It is thought that several rivers of this type, including the Athabasca and others, drained radially out from the relatively newly formed Front Ranges of the Rocky Mountains and were funnelled into the southeast-trending system represented in this area by the Helina Channel. Two tributaries extend northwards from the Helina Channel within the study area. One of these, the Sinclair Valley extends north from Marguerite Lake into the Cold Lake Air Weapons Range. In immediate preglacial time it appears to have been a tributary draining south into the Helina system. In the northwest of the study area, the Imperial Mills Valley appears to have at some preglacial time formed a link with the Helina Valley system and with the Wiau Valley in the northern part of the Air Weapons Range. This Wiau valley is several times larger than the Helina Valley and appears to be approximately 25 kilometres wide, 45 metres in depth and primarily filled with very well sorted fine sand. It is overlain by 150 to 250 metres of glacial deposits. It is a major groundwater resource but does not appear to be hydraulically connected with the preglacial channels present within the study area.

In addition to the channels previously mentioned in the southwest of the area, the Kikino Valley joins the Beverly Valley from the northwest. It is also thought to be of preglacial origin and

connects with the Helina Valley to the west of the study area. The Vermilion Valley, running north along the Alberta/Saskatchewan border, is also thought to be preglacial. Several valleys, presumed to be of glacial origin, also exist within the study area. These are the Holyoke Valley, the Bronson Lake Valley, the Big Meadow Lake Valley, the Vegreville Valley and the St. Paul Valley. The only one of these valleys of major importance for groundwater resources is the Bronson Lake Valley which extends south-southeast from the Beverly Valley to the north of Moose Lake.

2.3 Surficial Stratigraphy and Hydrostratigraphy

The preglacial erosion represented by the valley systems previously described was terminated by the onset of glaciation in the Pleistocene Era. Several ice sheets advanced and retreated through the area, eroding underlying deposits and depositing new till layers. Between glaciations, drainage attempted to resume its interrupted course. On the high ground between the channels only the most recent till deposits seem to be readily identifiable. Within the valleys themselves, several till layers have been identified. In general terms, therefore, surficial aquifers should be expected between or below major till sequences and not within them. While it is certainly true that local sand lenses may well be found within particular till units, it is only when sub-aerial river drainage and erosion take place that the well sorted sands and gravels required for groundwater aquifers are of any regional importance. The till and inter-till stratigraphic units were first described in Gold (1979). These descriptions have been refined and given formal formation names by Andriashek and Fenton (in preparation). The lowermost surficial aquifer is found in the Empress Formation. It consists primarily of preglacial sands and gravels within the confines of the preglacial valley floors. In the eastern part of the study area (as far west as Range 5) this formation may be divided into the Upper and Lower Empress, based on the presence of a thin clay

layer separating the two. Further west this clay layer is absent and the Empress Formation is considered to be a single entity. The Empress Formation is found more or less continuously throughout the Beverly Valley, the Helina Valley and the northwest portion of the Bronson Lake Valley. It also appears to exist in the southern part of the Sinclair Valley and probably also in the Imperial Mills Valley, although these two tributaries are less well defined because of the absence of drilling information in their northern parts.

Overlying the Empress Formation is the Bronson Lake till. On the basis of drill hole records, this till has not been identified continuously throughout the study area. Above this is the next interglacial deposit, the Durlingville. This again is confined to the Beverly and Helina Valleys as well as parts of the Imperial Mills, Sinclair and Bronson Lake Valleys. In particular, it appears to have larger groundwater potential than the Empress Formation since by this time the preglacial valleys had been partially filled and the resulting valley floor was shallower and wider. The Durlingville Formation is therefore the most important groundwater resource within the study area. In general confined to the valleys, it has however, extended in some places across some interfluves (for example, between the Helina and Beverly valleys in the Moose Lake area), although in these cases it is relatively thin and may be insignificant from a hydrogeological point of view.

Overlying the Durlingville is the Bonnyville Formation. Above this are found, in some parts of the study area, the Ethel Lake clays and sands, the overlying Medley till, then the Beaver River sands and finally the till of the Grand Centre Formation. Inter-till aquifers of either Ethel Lake or Beaver River origin are present in various parts of the study area but are not usually of great lateral extent. They are however of particular interest in the Sinclair Valley area partly because of their thickness and partly because of their industrial potential. It is unfortunate that little is known about the lateral

extent of these sands within the Sinclair Valley since the bulk of the valley falls within the Cold Lake Air Weapons Range and very little information is available.

In summary, the main groundwater aquifers are found within predominantly preglacial valleys incised into the underlying Cretaceous shales. While four preglacial or interglacial sand and gravel aquifers are of some interest, only two, the Empress and the Durlingville Aquifers are of major regional importance. On the basis of work done by the Earth Sciences Division, as well as by the Alberta Geological Survey, the greatest emphasis was therefore placed on the delineation of the Empress and Durlingville Formations and their evaluation for groundwater supply potential.

Chapter 3

DESCRIPTION OF THE NUMERICAL MODEL

The geological setting of the study area indicates complex aquifer geometry and hydrogeologic processes to be modeled. A finite element aquifer flow model, which has flexibility in representing the complicated aquifer domain and in handling various boundary conditions acting on the aquifer system, was chosen for this study. This aquifer computer code, AQUIFEM-1 (AQUIfer Finite Element Model-1-layer), was developed by Townley and Wilson (1980) at the Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, Massachusetts Institute of Technology. The model solves the equation describing two-dimensional, horizontal groundwater flow in a non-homogenous anisotropic aquifer with leakage. AQUIFEM-1 is formulated using the Galerkin finite element technique and uses linear interpolation functions with triangular elements. Steady state or transient solutions for confined, phreatic and changing status (confined to phreatic or vice versa) aquifers can be computed. Numerous boundary conditions such as recharge and pumping wells, lateral inflows and outflows, leakage from an adjacent aquifer and the exchange of water between the aquifer and fully or partially penetrating surface water bodies can be included. This practically oriented computer code was verified with analytical solutions and has been applied by the original developers to solve numerous flow problems in the subsurface environment. The mathematical formulation of the model is outlined in Appendix A which contains the following information: governing equation and boundary conditions, Galerkin finite element formulation and solution techniques for solving the system of matrix equations. Both steady state and transient responses of the Empress and Durlingville Aquifers were studied with this numerical model.

At the beginning of this study, consideration was given to modelling the surficial aquifers in the study area with either a three dimensional (3-D) flow model or a multilayered flow model. The two dimensional flow model described previously was used instead because of economic and time constraints on this study and the inadequate hydrogeologic data base to define the 3-D system and to calibrate the model. A more detailed discussion on the feasibility of 3-D modelling is presented in Appendix B.

Chapter 4

AVAILABLE DATA

4.1 Aquifer Stresses

Stresses acting on an aquifer result primarily from groundwater withdrawals and recharge. To simulate the impact of pumpage during the simulation period, groundwater users in each aquifer system have to be identified for that period. Suncor Inc. Resources Group (formerly known as Worldwide Energy Company Ltd.) and Amoco Canada Petroleum Energy Ltd. were users of the Empress Aquifer. Union Texas of Canada Ltd., Municipal District of Bonnyville and Norcen Energy Resources Ltd. obtained groundwater from the Durlingville Aquifer. Pumping records submitted by these users to the Ground Water Rights Branch of Alberta Environment were provided as weekly or monthly production volumes. Based on these records, average monthly pumping rates were calculated for 1980 at each groundwater withdrawal center. When there were several pumping wells in a pumping center, their withdrawals were represented as a cumulative nodal withdrawal. Figure 4.1 presents simplified pumping records of water users for each aquifer. Each step function is considered as an estimate of the actual pumpage at the withdrawl center during 1980.

Groundwater recharge to the Empress and Durlingville Aquifers is a difficult parameter to evaluate in the hydrogeologic system. This parameter, which is a function of many physical and climatological factors, can vary in time and space. For shallow aquifers, a mass balance analysis may provide an estimate of the net recharge component. For deep confined aquifers, like the Empress and Durlingville which are several hundred feet below the ground surface, the vertical flux through the till layer into the aquifer can be estimated from Darcy's Law. To compute this flux, the till hydraulic conductivity and the hydraulic

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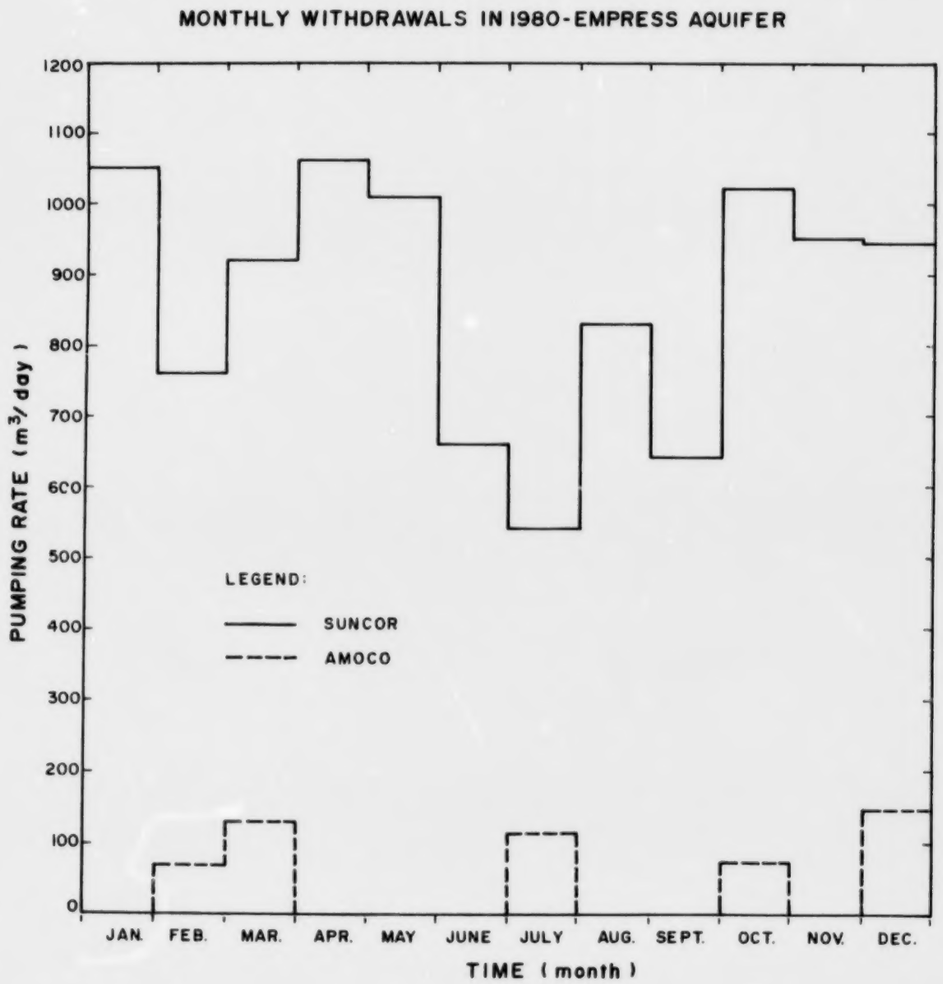

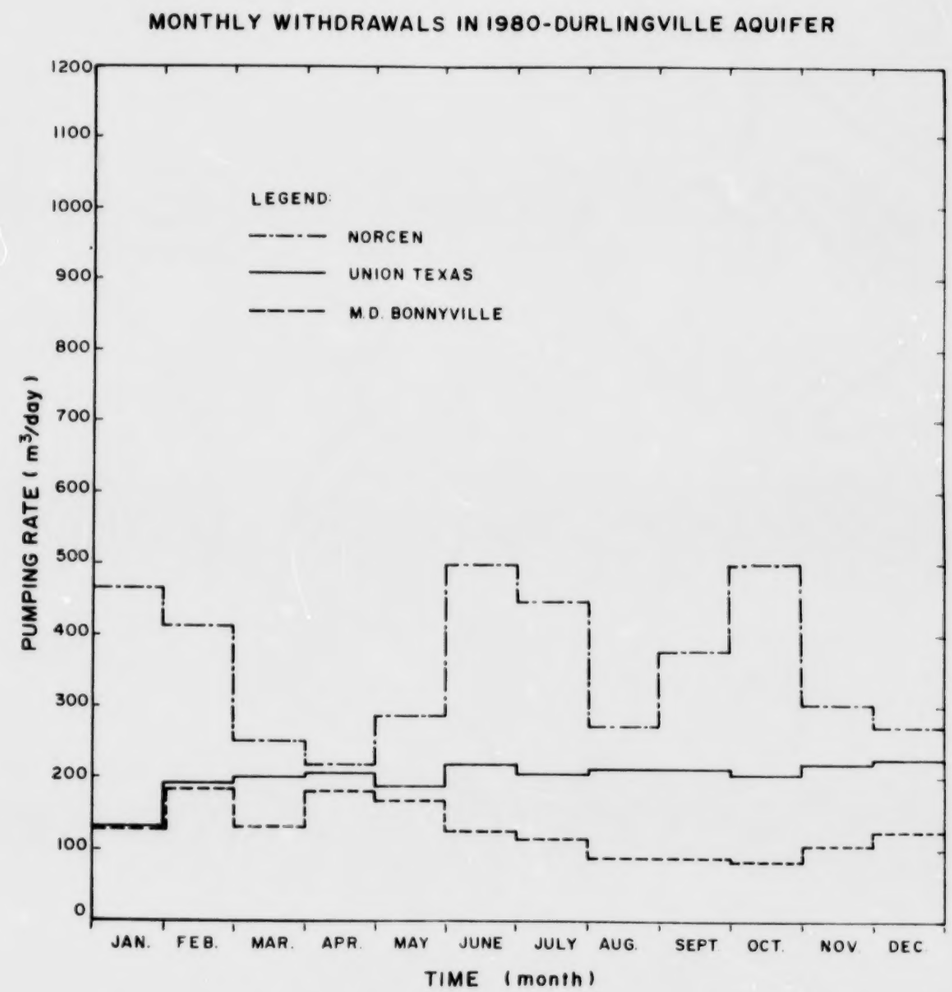

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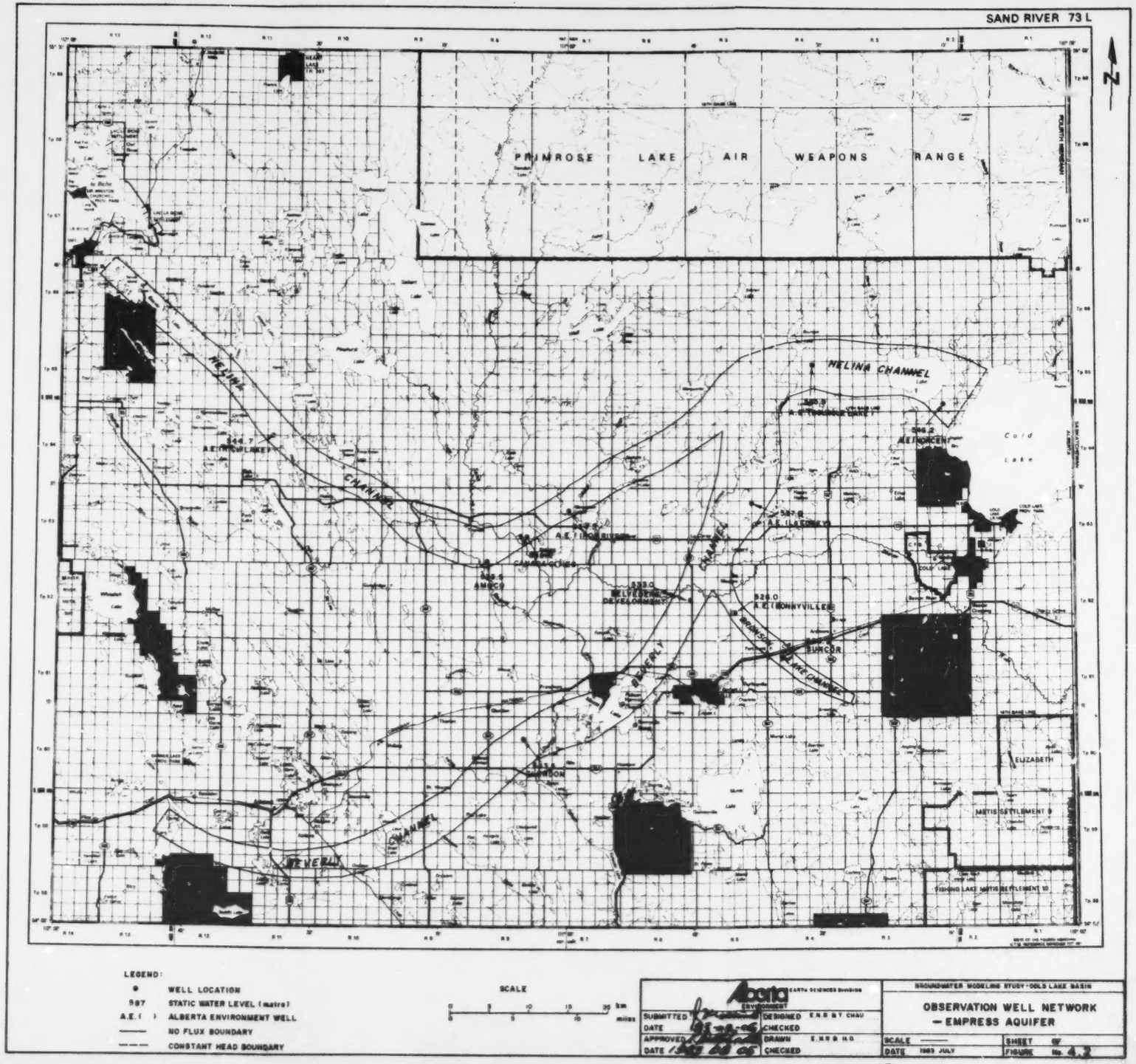
gradient across the till unit must be known. The hydraulic gradient is difficult to determine on a basin wide scale because of the limited information on piezometric heads. Also, the range in hydraulic conductivity can be quite significant. Analysis performed by the Groundwater Branch of the Alberta Research Council on data in the study area showed that the hydraulic conductivity of the till unit overlying the Empress Formation can vary between 4.3×10^{-8} m/sec and 2.4×10^{-7} m/sec. In this study, the net recharge rate to each aquifer was estimated through a trial-and-error approach during calibration of the model. With several uniformly distributed recharge rates as input, the simulation model was used to compute a steady state hydraulic head distribution using boundary conditions acting at the beginning of the simulation period. The recharge rate that gave the best match between observed and computed piezometric heads was considered to be the best estimate of the recharge component. This recharge rate was used in the subsequent transient simulation and in the prediction of aquifer responses to various groundwater withdrawal scenarios.

4.2 Observation Well Network

A network of observation wells is necessary to define the piezometric head distribution and hence the regional flow direction in an aquifer system. These observed piezometric heads also form the basis of comparison with the hydraulic heads computed by the model. Figures 4.2 and 4.3 summarize, respectively, the static water level (above mean sea level) of observation wells in the Empress and Durlingville Aquifers. In order to obtain accurate water levels, surveying has been completed by the Survey Branch to obtain ground elevations of all Alberta Environment wells and some industrial wells in both aquifers. Table 4.1 provides the location of these wells for both aquifers. These wells will be constantly referred to by their names given in this table for the rest of the report. Continuous water level records are available for the A.E. (Bourque Lake) wells since March, 1980 and for the A.E. (Bonnyville) wells since August, 1977. The rest


SAND RIVER 73 L
PRIMROSE LAKE AIR WEAPONS RANGE
HELINA CHANNEL
HELINA CHANNEL
BEVERLY CHANNEL
BEVERLY CHANNEL
BRANSON LAKE CHANNEL
Cold Lake
ELIZABETH
METIS SETTLEMENT 9
FISHING LAKE METIS SETTLEMENT 10
LEGEND:
WELL LOCATION
587 STATIC WATER LEVEL (metre)
A.E.( ) ALBERTA ENVIRONMENT WELL
NO FLUX BOUNDARY
CONSTANT HEAD BOUNDARY
SCALE
km
miles
Alberta ENVIRONMENT
EARTH SCIENCES DIVISION
SUBMITTED
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APPROVED
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DESIGNED E.N.R. & T. CHAU
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GROUNDWATER MODELING STUDY - COLD LAKE BASIN
OBSERVATION WELL NETWORK
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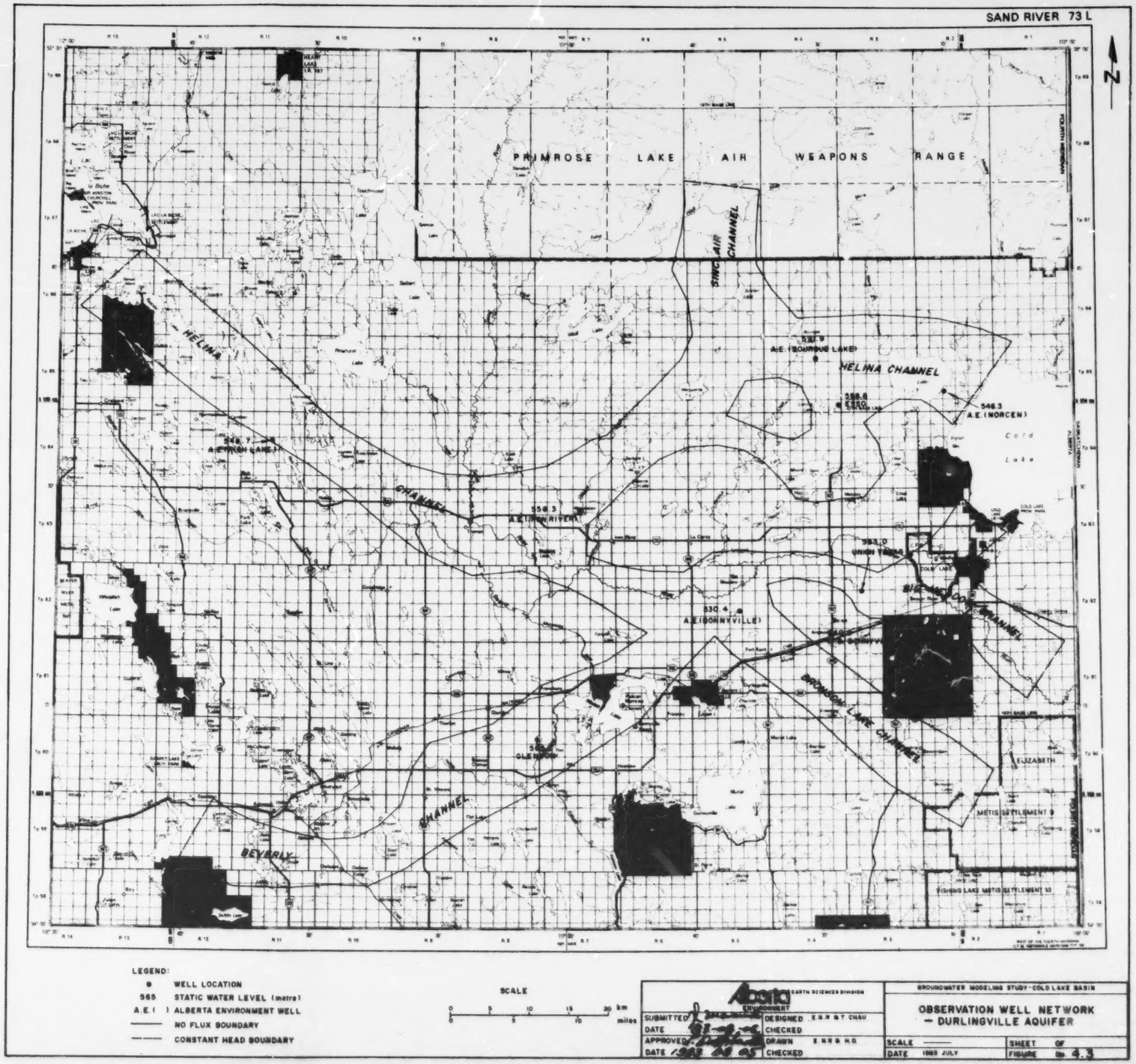
SAND RIVER 73 L
PRIMROSE LAKE AIR WEAPONS RANGE
SINC AIR CHANNEL
HELINA CHANNEL
HELINA
CHANNEL
BEVERLY
CHANNEL
BRONSON LAKE CHANNEL
Cold Lake
A.E. (BOURQUE LAKE)
A.E. (NORCEN)
A.E. (BONNYVILLE)
A.E. (RIVER)
ELIZABETH
METIS SETTLEMENT 9
FISHING LAKE METIS SETTLEMENT 10
LEGEND:
WELL LOCATION
565 STATIC WATER LEVEL (metre)
A.E. ( ) ALBERTA ENVIRONMENT WELL
NO FLUX BOUNDARY
CONSTANT HEAD BOUNDARY
SCALE
km
miles
Alberta ENVIRONMENT
EARTH SCIENCES DIVISION
SUBMITTED
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GROUNDWATER MODELING STUDY - COLD LAKE BASIN
OBSERVATION WELL NETWORK
— DURLINGVILLE AQUIFER
SCALE
DATE 1983 JULY
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FIGURE No. 4.3

TABLE 4.1

Location of Wells in Empress and Durlingville Aquifers*

Well name	Well location	Empress Aquifer	Durlingville Aquifer
A.E. (Bonnyville)	NE-15-62-5-W4	P	P
A.E. (Bourque Lake)	SW-26-65-4-W4	P	P
A.E. (BP)	SW-28-66-5-W4		
A.E. (Iron River)	SW-27-63-7-W4	P	P
A.E. (La Corey)	NW-25-63-5-W4	P	
A.E. (Norcen)	SW-9-65-2-W4	P	P
A.E. (Rich Lake)	SW-27-64-11-W4	P	P
Amoco	SW-4-63-8-W4	P	
Belvedere Development	SW-19-62-5-W4	P	
Canada Cities	SW-13-63-8-W4	P	
Esso	NE-1-65-4-W4		P
Glendon	SE-26-60-8-W4	P	
M.D. Bonnyville	SE-32-61-4-W4		P
Suncor	SW-28-61-4-W4	P	
Union Texas	NW-20-62-3-W4		P

* For all A.E. wells, P implies the completion of well in that particular aquifer. For the rest of the wells, P also means potential groundwater use from the aquifer.

of the Environment wells were constructed during 1981 and 1982, in an attempt to establish the flow pattern and to obtain more data on aquifer properties. No recorders were installed at that time to monitor water level changes. In the near future, recorders will be installed in these wells so that the impact of basin wide groundwater development can be measured on a continuous basis. In this study, the A.E. (Bonnyville) well, which had continuous water level readings during 1980, was used to calibrate the model for both aquifers. In addition to production wells in a pumping center, there were associated observation wells for monitoring of water level changes during the simulation period. The measured responses at these observation wells were not used for model calibration because the finite element grid was primarily designed for regional application. A very fine mesh is required in the proximity of the production wells in order to generate the transient responses for comparsion with those observed at these observation wells.

The piezometric heads given in figures 4.2 and 4.3 were constructed from static water levels measured at different times (several years apart between two measurements in some cases). Hence, the piezometric heads supplied in both figures should not be taken as a snapshot of the aquifer response at some point in time. These heads, in effect, could reflect the changes in hydrogeologic events in the basin over a period of many years. These changes can be significant for a basin undergoing intense groundwater development. This time factor should not be overlooked if these maps are used to infer aquifer flow patterns.

Based on the piezometric heads in figure 4.2, several characteristics are apparent for the Empress Aquifer. First, high heads were measured in Alberta Environment wells near Bourque Lake and La Corey. Secondly, observed heads near La Corey and Belvedere Development suggested the existence of a sharp hydraulic gradient between these two locations (about 50 metres head difference over 15 kilometres). Thirdly, along the Helina Channel, heads measured at Canada Cities and Amoco were lower than that recorded by the Alberta Environment Wells

(A.E. (Iron River) and A.E. (Rich Lake)). This appears to indicate a convergence in flow towards the area where Amoco and Canada Cities are located. If that is the case, there has to be a source of outflow for these incoming flows around that area in order for the flow dynamic to be physically reasonable. To sum up, existing piezometric heads do not provide a consistent and clear picture of the flow distribution in the Empress Aquifer system.

Figure 4.3 is used to analyze flow patterns in the Durlingville Aquifer. High heads were observed at the A.E. (Bourque Lake) Well and the Esso Resources Well. This may indicate a dominant flow coming from the north through the Sinclair Channel. This is then divided into two components at the channels confluence, one component flowing along the Helina Channel towards Lac La Biche and another component directed towards Cold Lake. Along the Bronson Lake Channel, static water levels show that flow is from the east towards the junction of three channels (Beverly, Bronson Lake and Big Meadow). Comparing the static water level of Union Texas Well to the slightly higher lake level of Cold Lake seems to indicate outflow from the lake through the tributary connected to the Big Meadow Channel. The flow in this tributary is divided into an east and west component along the Big Meadow Channel. Based on piezometric heads recorded at wells near Glendon and another well (6-27-59-12-W4), flow along Beverly Channel is from the west towards the east. Previous discussions illustrate flow towards the junction of the three channels. This may suggest possible hydraulic connection between the aquifer and the Beaver River which might serve as a discharge zone for the aquifer.

4.3 Aquifer Properties

Aquifer properties (transmissivity and storage coefficient) have to be determined for the aquifer modelling domain. The transmissivity is defined as the rate of flow per unit width through the entire depth of the aquifer under a unit hydraulic gradient. The

storage coefficient provides the relationship between changes in the amount of water stored in the aquifer and changes in head. Under the steady state situation ($\frac{\partial h}{\partial t} = 0$), the storage coefficient is not required in the computation of the steady head distribution. It is needed only in transient analysis. Pumping tests, a technique for the identification of aquifer properties, were conducted at different locations in the river basin. A summary of aquifer parameters obtained by pumping tests was contained in the report prepared by MLM Groundwater Engineering (1982). Based on their results, logs and lithology data, transmissivities were estimated for the aquifer domain. Since some of the pumping tests were performed with only a source well, the storage coefficient could not be estimated by conventional pumping test techniques. Hence, the data base for the storage coefficient over the modelling region was very limited. Using a range of values for the storage coefficient in the transient simulation, the storage coefficients that gave the best match between the model and the observed response were assigned to the aquifer system.

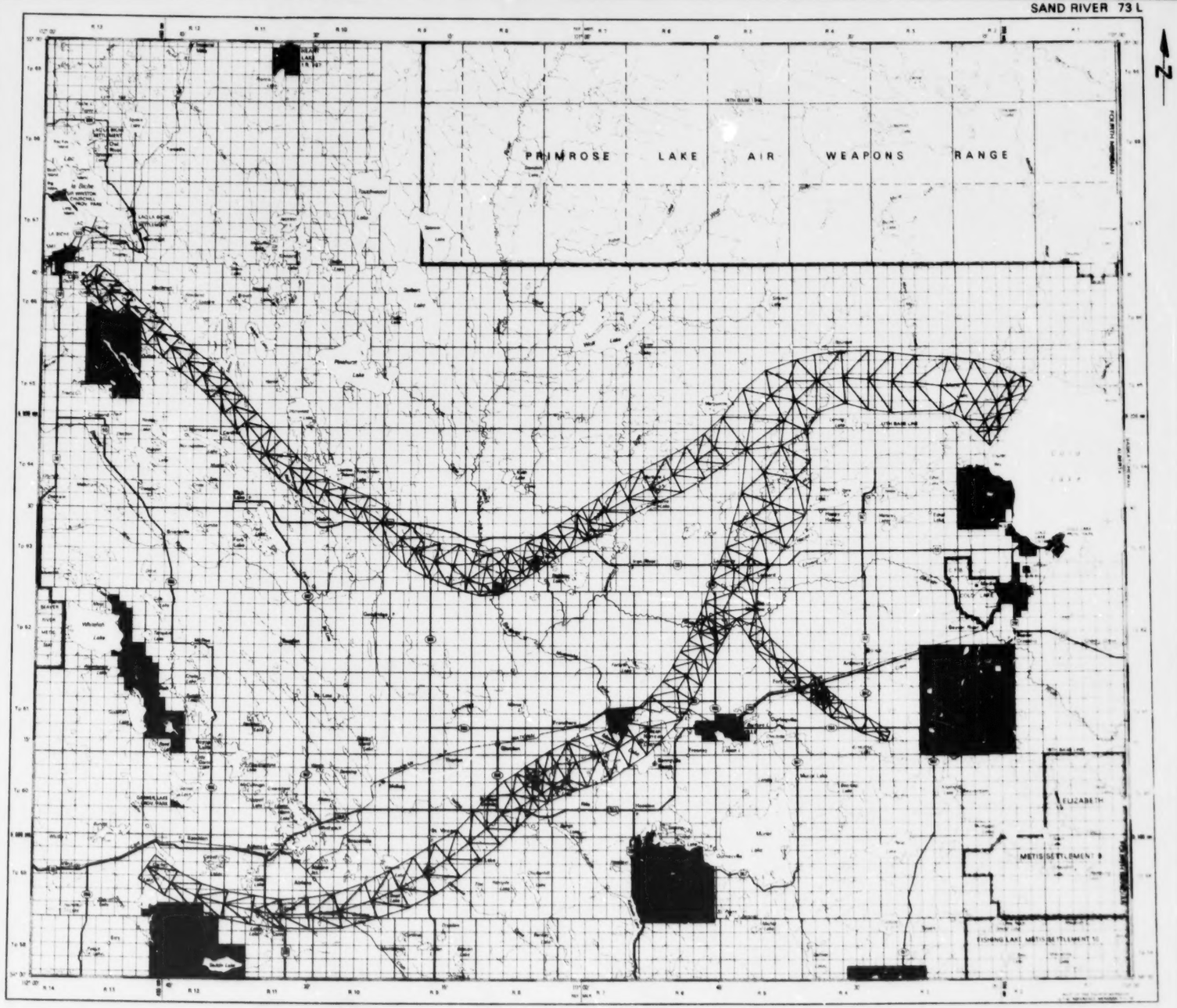
Chapter 5

APPLICATION OF MODEL TO EMPRESS AQUIFER

5.1 Aquifer Description and Specification of Boundary Conditions

The triangular grid which represents the modelling region is presented in figure 5.1. The grid was discretized into 545 elements (triangles) with 380 nodes. Closely spaced nodes were placed around potential groundwater withdrawal centers because of the rapid change in piezometric heads around them. These pumping centers include Amoco Canada Petroleum Energy Ltd., Canada Cities Services Ltd., Belvedere Development Ltd., Suncor Inc. Resources Group and Village of Glendon. Despite the large number of elements used, the finite element mesh was only designed for regional application. For the finest portion of the mesh, distance between adjacent nodes is about 300 metres. Most pumping centers have several pumping wells and associated observation wells. Because of the regional scale considered in this study, the cluster of wells in a pumping center could be adequately represented by a single node. When localized modelling is required in the future and there is insufficient data to define the fine mesh boundary conditions, the boundary nodal points of the fine mesh can be designed to merge with existing nodes of the regional mesh. In this manner, the prescribed boundary heads for the fine mesh are given by the computed heads of the regional mesh.

No flux or constant head boundary conditions were specified along the boundaries of the Empress Aquifer. If the recharge and the underflow into or out of the modelling boundary were sufficient to maintain a nearly constant piezometric head, the constant head assumption was introduced along that boundary. The no flux boundary condition was applied when the flow direction was essentially parallel to that boundary, implying that the flux through the channel wall was negligible. In figure 4.2, dotted lines indicate constant head



SCALE

0 5 10 15 20 km

0 5 10 miles

Aosta ENVIRONMENT EARTH SCIENCES DIVISION		GROUNDWATER MODELING STUDY - COLD LAKE BASIN
SUBMITTED	DESIGNED E.N.R. & T. CHAU	FINITE ELEMENT MESH OF EMPRESS AQUIFER
DATE 83-08-05	CHECKED	
APPROVED	DRAWN E.N.R. & H.O.	SCALE — / SHEET OF
DATE 1983 AUG 05	CHECKED	DATE 1983 JULY / FIGURE No. 5.

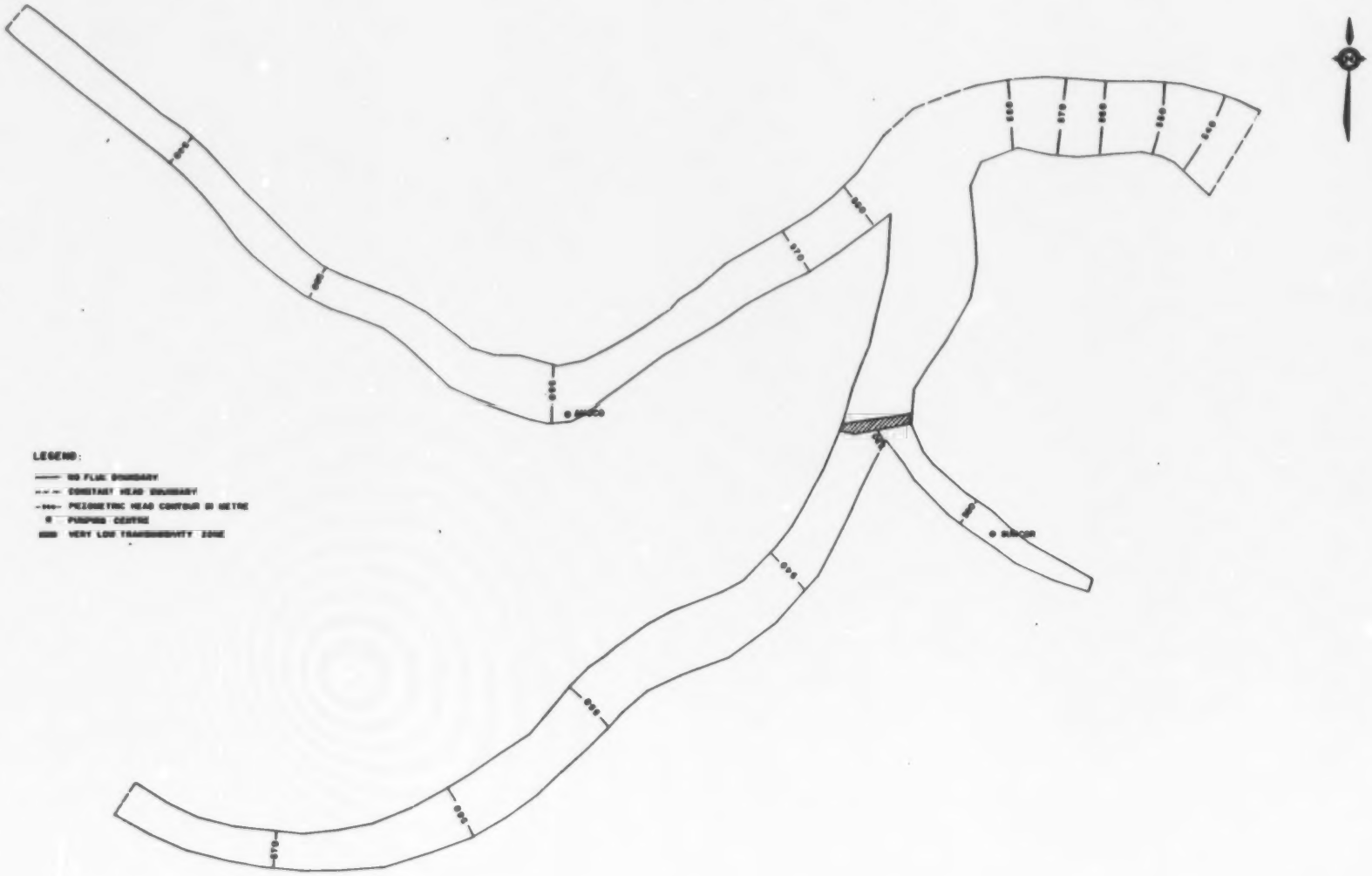
boundaries and no flow boundaries are represented by solid lines. Surficial stratigraphy along the Bronson Lake Channel indicated that the aquifer gradually pinched out. A no flux boundary condition was prescribed at the end of this channel. The water level of Cold Lake and static water level of a well near Vincent Lake provided, respectively, the constant head boundary conditions for the east end of the Helina Channel and west end of the Beverly Channel. Along the confluence of three channels (Sinclair, Helina and Beverly), a constant head boundary was used. There was an insufficient data base to understand the geology of the confluence region in detail. The continuity of the Empress Aquifer into the Sinclair Channel was of limited extent based on the available geological data. The high piezometric heads recorded by the Alberta Environment wells near Bourque Lake and La Corey seem to suggest a dominant flow arriving from the north through the Sinclair Channel. This main stream is divided at the channel junction into several flow components. One component flows east through the Helina Channel into Cold Lake. Other components flow south through the Beverly Channel towards La Corey and west through the Helina Channel towards Lac La Biche. The static water levels observed in wells near Vincent Lake, Glendon and Belvedere suggest that flow along this reach of the Beverly Channel is from Vincent Lake towards Belvedere. To explain the observed sharp drop in heads between La Corey and Belvedere, the geological setting of this area was subsequently re-interpreted. This area suggests a discontinuity which is similar to the presence of a geologic fault in the Beverly Channel. Horizontal flow across this fault is prohibited. To simulate this geologic discontinuity with the model, very low transmissivity values were assigned to the elements covering this discontinuous zone. The presence of this discontinuity implies two independent flow regimes within the Empress Aquifer system.

The northern limit of the modelling boundary was limited by the southern boundary of the Cold Lake Air Weapons Range, an establishment

of the Department of National Defense. The continuity of the Sinclair Channel could not be established north of Township 66 because hydrogeologic information was not available for the area. Within the Sinclair reach considered for this study, observation wells owned by Alberta Environment and BP Exploration Canada Ltd. were available to define piezometric heads only in the surficial aquifer overlying the Durlingville Aquifer. To define the unknown constant head boundary condition along the channels confluence, several boundary heads were used for model input. By this trial and error procedure, the boundary head selected was the one that best simulated the observed response of the aquifer system.

5.2 Calibration of Model

A spatial hydraulic head distribution at the start of the simulation period was required to carry out the transient analysis. It was originally intended to construct this initial head distribution from the observation well network in the Empress Aquifer. The limited observation wells were insufficient to provide a general picture of the flow direction. It would be even more difficult to generate the initial hydraulic heads at all nodal points of the aquifer mesh. This initial condition was obtained by assuming a steady state condition prevailed at the start of the simulation period. Using equation A.14 given in Appendix A, a steady state solution was computed with the boundary conditions and stresses acting at the beginning of the simulation period. The computed steady state hydraulic head distribution, serving as an initial condition for the transient simulation, is presented in figure 5.2. The observed static water levels in figure 4.2 form the basis of comparison with the computed steady state piezometric distribution at the start of 1980. Since the observed piezometric heads were based on static water levels measured at different times, they might not necessarily represent actual water levels at the beginning of 1980. This factor should be considered when making the comparsion.



Alberta Environment — Earth Sciences Division		GROUNDWATER MODELLING STUDY - COLD LAKE BASIN
SUBMITTED	DESIGNED T. CHAU	PIEZOMETRIC MAP OF EMPRESS AQUIFER AT THE BEGINNING OF 1980
DATE	CHECKED	
APPROVED	DRAWN	SCALE AS SHOWN — SIZE
DATE	CHECKED	DATE JULY 1983 — FIGURE No. 9.2

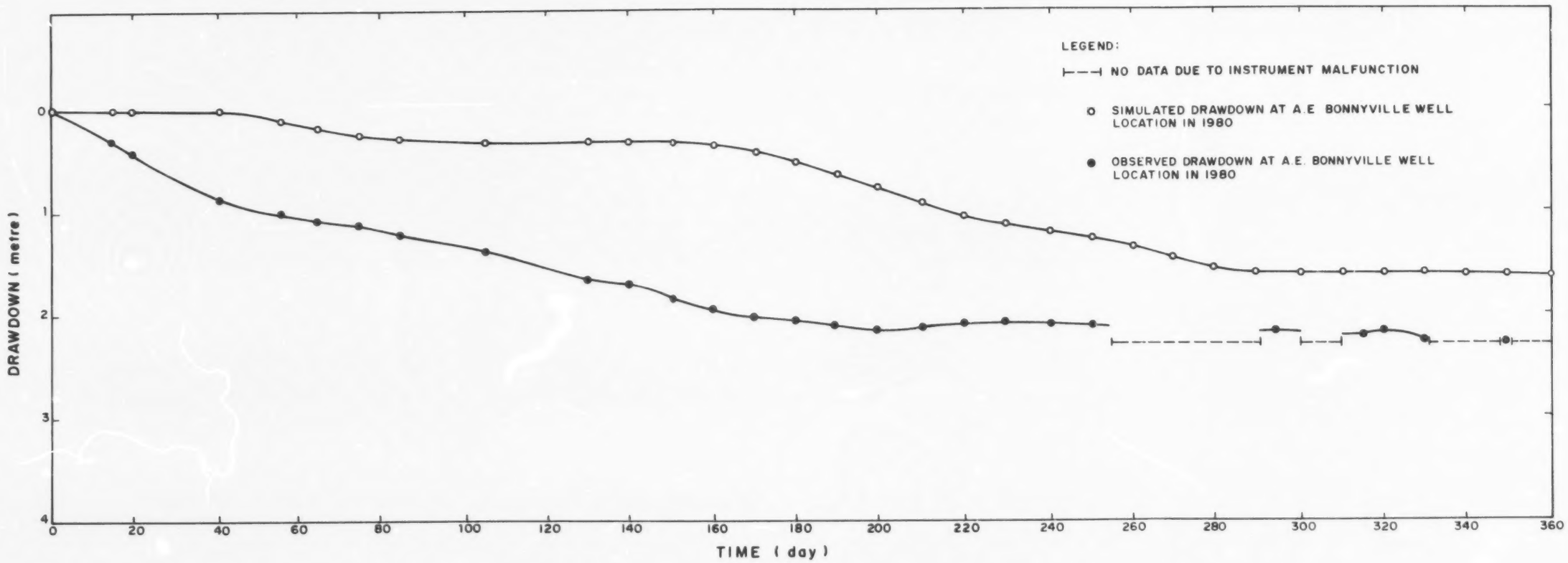
Table 5.1 provides a comparison between the observed and computed heads at specific locations. There are large discrepancies in heads (about 30 metres) at the Amoco and Canada Cities locations. Model simulation gave rise to unidirectional flow in that reach of the Helina Channel. This contradicts the inference drawn from the observed heads which indicate a convergence in flow towards the Amoco and Canada Cities locations. During 1980, Amoco was the only groundwater withdrawal location and the production rates were by no means high enough to create such an observed flow pattern. There had to be another means of outflow in order to induce flow from both ends of the channel. Because of the limited data base for that part of the Helina Channel, the geology of many locations was unknown. This leaves the possible outflow locations open to speculation. Perhaps there is hydraulic connection between the Sand River and the Helina Channel. The bedrock formation for some part of the channel may not be as impervious as assumed for this study. Hence, it can act as a discharge zone for the Empress Aquifer. The same applies to possible lateral outflow from the valley wall. Refined geological interpretation for this reach is necessary as more data becomes available in the future. The model will then be modified to include this new boundary condition. On the whole, there is reasonable agreement between observed and computed heads at most locations in the Beverly and the Bronson Lake Channels. The discrepancy in heads at A.E. (Bourque Lake) and A.E. (Norcen) wells was due to the lack of information to specify boundary condition at the confluence of three channels.

Transient aquifer response for the simulation period was calculated with the steady state computed head distribution as the initial condition, using equations A.15 to A.17 in Appendix A. Water levels observed in the Alberta Environment well near Bonnyville during 1980 were compared with the computed hydraulic heads. These results are shown in figure 5.3. It appears that there is a time lag between the observed and simulated response curves. From May onward, the shape

TABLE 5.1

Observed and Computed Steady State Heads in the Empress Aquifer

Well location	Observed head (m)	Computed head (m)
A.E. (Bonnyville)	526.0	524.0
A.E. (Bourque Lake)	585.9	577.7
A.E. (Iron River)	554.5	565.9
A.E. (La Corey)	587.0	586.6
A.E. (Norcen)	546.2	538.6
A.E. (Rich Lake)	544.7	546.9
Amoco	533.5	560.7
Belvedere	533.0	531.5
Canada Cities	532.0	562.7
Glendon	543.5	547.6
Suncor	526.2	518.0



Alberta ENVIRONMENT — EARTH SCIENCES DIVISION		GROUNDWATER MODELING STUDY-COLD LAKE BASIN
SUBMITTED	DESIGNED T. CHAU	OBSERVED AND SIMULATED DRAWDOWNS – EMPRESS AQUIFER
DATE 83-08-05	CHECKED	
APPROVED	DRAWN H.O.	SCALE —— / SHEET / OF
DATE 1983 08 05	CHECKED	DATE 1983 JUNE / FIGURE No. 5.3

MICROFILM DATE
DRAWING FILE No
CENTRAL FILE No
P3-280x430

of the simulated response curve resembles quite closely the observed response curve starting from February. This delayed response might arise from the use of a steady state solution as the initial condition in the simulation. It takes a longer time to start an aquifer system from a steady state as compared to a system that is undergoing dynamic changes. The entire aquifer system at the time might not necessarily be in a steady state, particularly for the Bronson Lake Channel which was having constant groundwater withdrawal by Suncor. In fact, the steady decline in water level as indicated by the Environment and Suncor observation wells prior to 1980 suggested that a steady state condition was not attainable for this channel. However, a steady state representation might be applicable to other parts of the aquifer system. Because there is no better means to define the initial head distribution, the steady state solution still provides a reasonable initial estimate.

Since the aquifer system responds to pumping changes on a smaller time scale, the use of constant monthly pumpages to represent the actual state of stress acting on the aquifer could introduce a significant source of error in the transient computation. However, the available pumping records did not justify using constant pumping rates of duration less than a month.

5.3 Sensitivity Study of Model Parameters

Sensitivity analysis was carried out with the model to assess the effect of parameter variations on the hydraulic head distribution in the Empress Aquifer. With the set of parameters used in the calibration of the model as a basic set, one parameter was varied at a time from its base value. Model parameters such as transmissivity, storage coefficient, recharge and boundary head were examined independently.

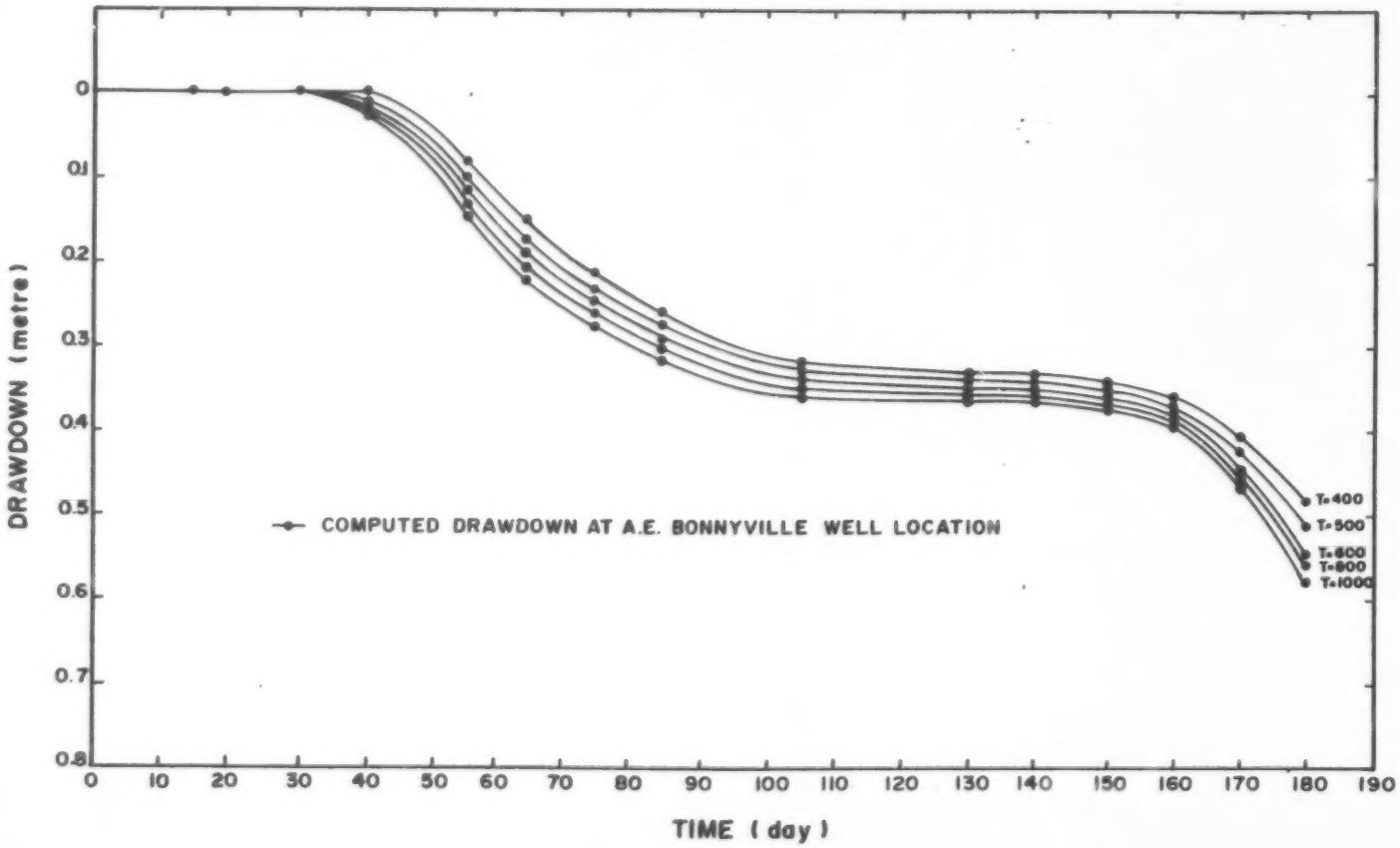
Transmissivity values, ranging between 400 m^2/day and 1000 m^2/day, were assigned to the Bronson Lake Channel. The corresponding transient response curves at the A.E. (Bonnyville) well

location are presented in figure 5.4. A 50 percent increase of transmissivity from 400 m^2/day produced only small changes in water levels. The maximum difference in heads between the two curves was 0.027 metres for the period considered. Raising the transmissivity 2½ times to 1000 m^2/day produced a maximum change in head of 0.093 metres.

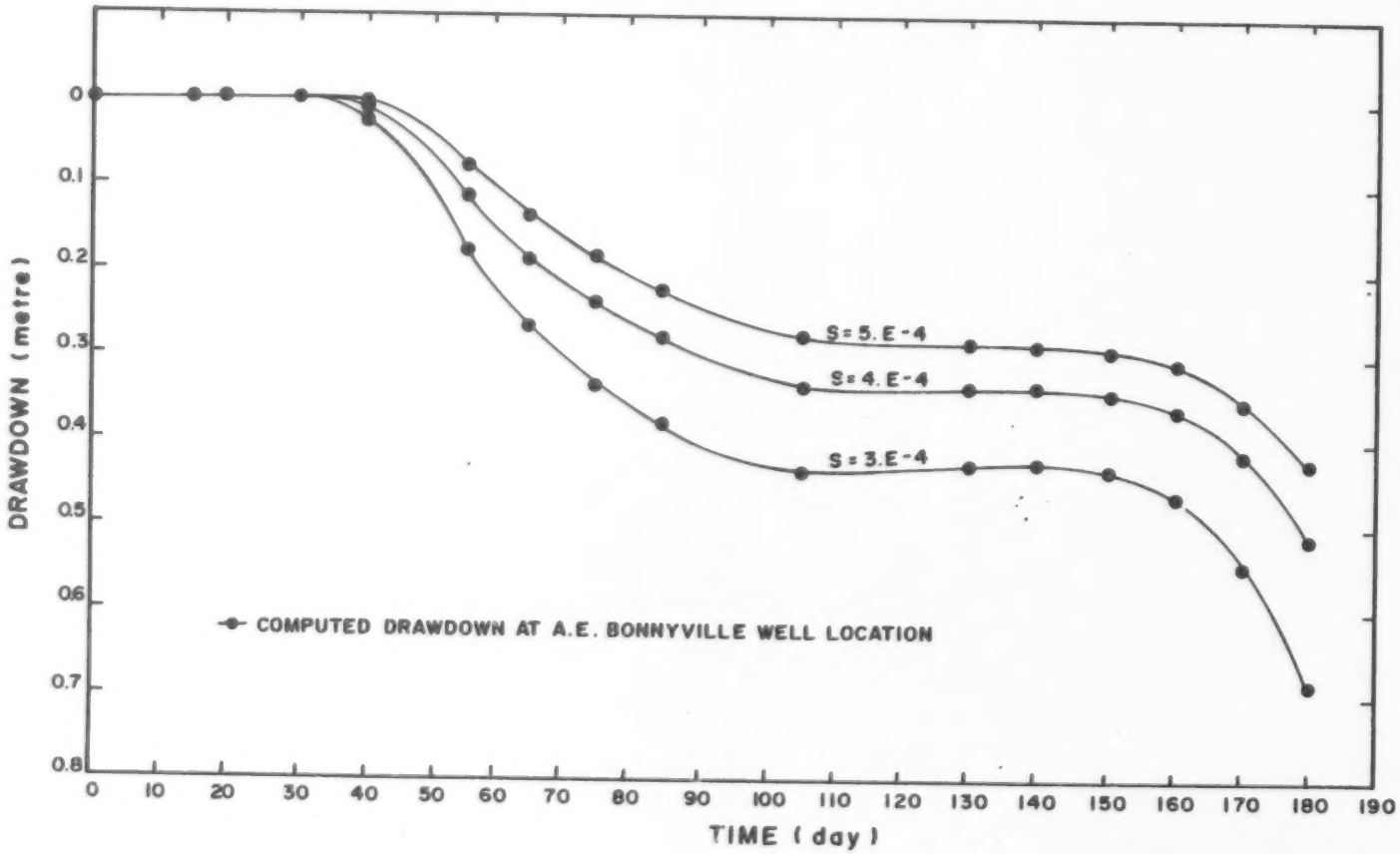
Water level response curves were computed at the location of A.E. (Bonnyville) well with different storage coefficients assigned to the Bronson Lake Channel. These results are shown in figure 5.5. For the six months considered, the aquifer response is more sensitive to changes in storage coefficient than transmissivity.

The recharge (10^{-7} m/day) was determined during model calibration. Table 5.2 shows the computed heads under steady state condition for different recharge rates. Computed heads at A.E. wells (La Corey, Bourque Lake and Norcen) were insensitive to changes in the recharge rates. On the contrary, heads computed for the Helina Channel west of the channel's confluence with the Beverly Channel were most sensitive to recharge changes. The difference in the response behaviour was due to low transmissivities and flow in this portion of the Helina Channel.

Since there was no reliable well to define the constant head boundary condition along the confluence of the channels, the inherent uncertainty of this boundary head was assessed with different boundary values. In calibrating the model, the boundary head used was 590 metres. Based on the sensitivity analysis results provided in table 5.3, water level change at each location was linearly proportional to the change in boundary head. The results also showed that the effect of boundary perturbation, as indicated by the water level changes in the aquifer domain, decreases with distance from that boundary.



Alberta ENVIRONMENT EARTH SCIENCES DIVISION		GROUNDWATER MODELING STUDY—COLD LAKE BASIN
SUBMITTED R. Moraninski	DESIGNED T. CHAU	SENSITIVITY STUDY WITH VARYING TRANSMISSIVITIES
DATE 83-08-05	CHECKED	
APPROVED L. D. McSadler	DRAWN H.O.	SCALE —— SHEET OF
DATE 1983 08 05	CHECKED	DATE 1983 JUNE FIGURE No. 5.4



Alberta ENVIRONMENT EARTH SCIENCES DIVISION		GROUNDWATER MODELING STUDY-COLD LAKE BASIN
SUBMITTED	DESIGNED T. CHAU	SENSITIVITY STUDY WITH VARYING STORAGE COEFFICIENTS
DATE 83-08-05	CHECKED	
APPROVED	DRAWN H.Q.	SCALE —— / SHEET OF
DATE 1983 08 05	CHECKED	DATE 1983 JUNE / FIGURE No. 5.5

TABLE 5.2

Effect of Recharge on the Steady State Hydraulic Heads in the Empress Aquifer

Well location	Observed head (m)	Computed head (m)		
		Recharge = 0 m/day	Recharge = 10^{-7} m/day	Recharge = 10^{-6} m/day
A.E. (Bonnyville)	526.0	522.6	524.0	536.0
A.E. (Bourque Lake)	585.9	577.6	577.7	577.8
A.E. (Iron River)	554.5	564.1	565.9	582.0
A.E. (La Corey)	587.0	586.6	586.6	587.4
A.E. (Norcen)	546.2	538.6	538.6	538.6
A.E. (Rich Lake)	544.7	545.5	546.9	560.3
Amoco	533.5	558.8	560.7	578.1
Belvedere	533.0	530.2	531.5	543.1
Canada Cities	532.0	560.8	562.7	579.8
Glendon	543.5	546.5	547.6	557.4
Suncor	526.2	516.7	518.0	530.2

TABLE 5.3

Effect of Boundary Head on the

Steady State Hydraulic Heads in the Empress Aquifer

Well location	Observed head (m)	Computed Head (m)		
		Boundary head = 590 (m)	Boundary head = 595 (m)	Boundary head = 600 (m)
A.E. (Bonnyville)	526.0	524.0	524.0	524.0
A.E. (Bourque Lake)	585.9	577.7	581.5	585.4
A.E. (Iron River)	554.5	565.9	568.7	571.5
A.E. (La Corey)	587.0	586.6	591.3	596.0
A.E. (Norcen)	546.2	538.6	538.9	539.2
A.E. (Rich Lake)	544.7	546.9	548.2	549.5
Amoco	533.5	560.7	563.1	565.5
Belvedere	533.0	531.5	531.5	531.5
Canada Cities	532.0	562.7	565.3	567.8
Glendon	543.5	547.6	547.6	547.6
Suncor	526.2	518.0	518.0	518.1

TABLE 5.4

Projected Groundwater Demand for the Empress Aquifer

User	Low Demand		High Demand	
	(dam^3/yr)	(m^3/day)	(dam^3/yr)	(m^3/day)
Amoco	1160	3178.4	2320	6356.8
Canada Cities	410	1123.4	750	2055.0
Glendon	120	328.8	270	739.8
Suncor	1160	3178.4		
Belvedere	168	460.8		

5.4 Predictive Capability

Future water withdrawal by industrial, municipal and domestic users in the basin has been projected by the Planning Division. The potential groundwater users of the Empress Aquifer consist of Amoco Canada Petroleum Company Ltd., Canada Cities Services Ltd., Village of Glendon, Suncor Inc. Resources Group and Belvedere Development Ltd. The groundwater demand for these users are summarized in table 5.4.

For a regional flow system, under constant pumping in time, a steady state solution would be suitable to describe the ultimate response of the aquifer system. To evaluate the effect of a particular groundwater mining scheme, the main criteria employed for this study was to maintain a confined aquifer status. Hence the piezometric head at the pumping location should always be maintained above the top of the aquifer. Simulation using both high and low demand schemes resulted in excessive drawdown at all pumping centers. To arrive at a long term feasible withdrawal scheme for potential groundwater users in the river basin, the analysis was undertaken in the following manner. Corresponding to different percentages (30%, 50%, 70% and 100%) of low demands, a steady state aquifer response was obtained for each excitation. The calculated piezometric head at each withdrawal location was compared with the top of the aquifer. If this head was above the aquifer top, the drawdown was acceptable. When the computed hydraulic head fell below the top of the aquifer, the calculated head based on the confined aquifer assumption did not necessarily represent the water table under unconfined condition. However, it did demonstrate a change of aquifer status had taken place. Consequently, the specified pumping demand at that location was not feasible. Table 5.5 presents the computed heads at the pumping centers for five different groundwater withdrawal schemes. Scheme 5 is considered a feasible pumping scheme. To identify this particular pumping scheme, results of table 5.5 for schemes one to four were plotted in figure 5.6 with head versus

TABLE 5.5

Steady State Responses To Several Pumping Schemes - Empress Aquifer

Pumping location	Aquifer top elevation (m)	Scheme 1		Scheme 2		Scheme 3		Scheme 4		Scheme 5	
		Pumping rate (m^3/day)	Head (m)	Pumping rate (m^3/day)	Head (m)	Pumping rate (m^3/day)	Head (m)	Pumping rate (m^3/day)	Head (m)	Pumping Rate (m^3/day)	Head (m)
Amoco	484	3180.0	166.8	2225.1	285.0	1589.1	363.8	953.4	442.6	477.0	496.9
Canada Cities	469	1123.5	192.4	786.3	303.6	561.6	377.7	336.9	451.7	224.7	502.0
Glendon	504	328.8	453.4	230.1	491.9	164.4	517.5	98.7	543.2	164.4	528.5
Suncor	477	3180.0	354.1	2225.1	422.5	1589.1	468.0	953.1	513.6	1272.0	488.6
Belvedere	486	460.8	397.2	322.6	452.6	230.4	489.5	138.2	526.5	207.4	505.8

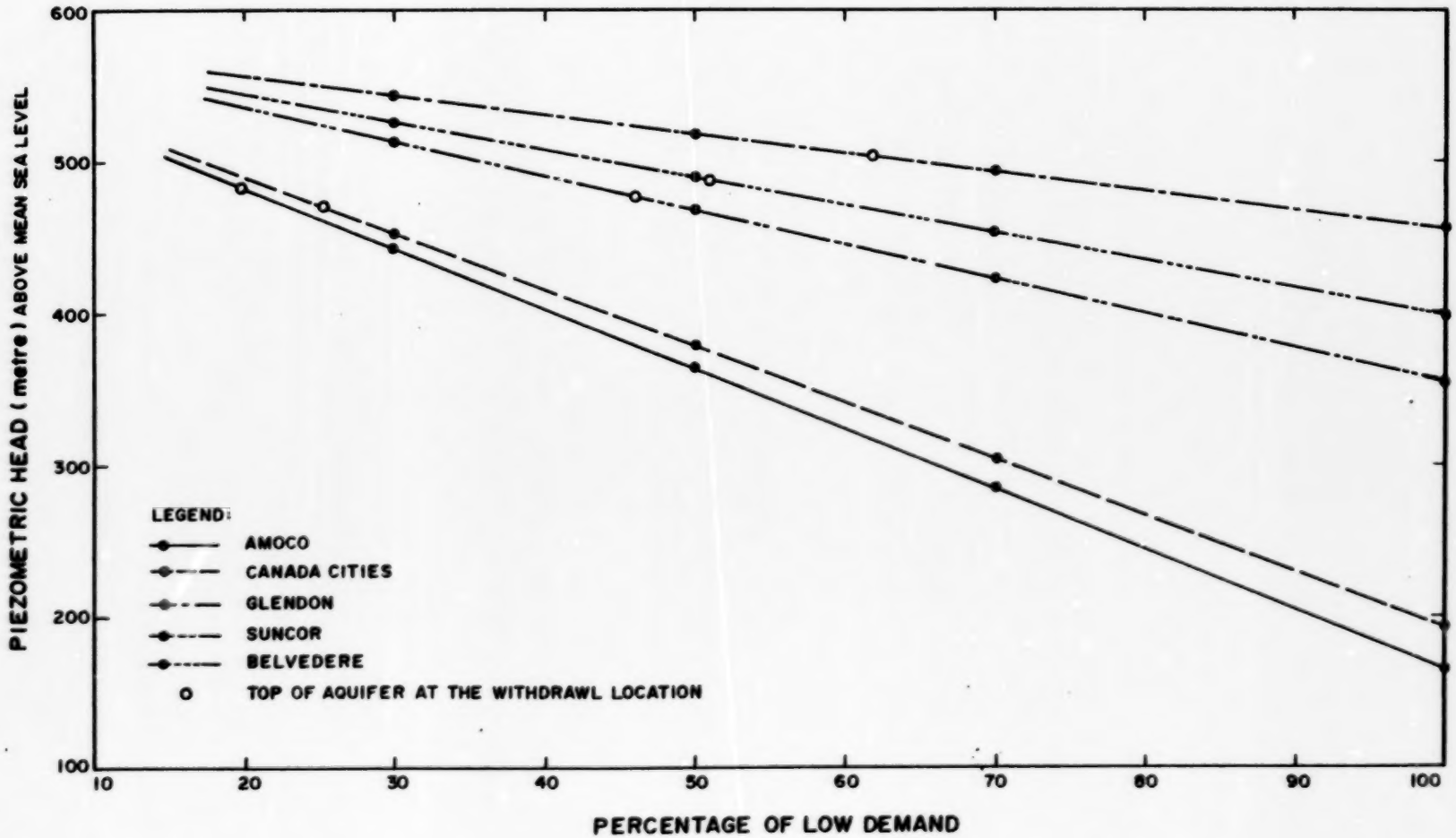
Scheme 1 - 100% of low demand

Scheme 2 - 70% of low demand

Scheme 3 - 50% of low demand

Scheme 4 - 30% of low demand

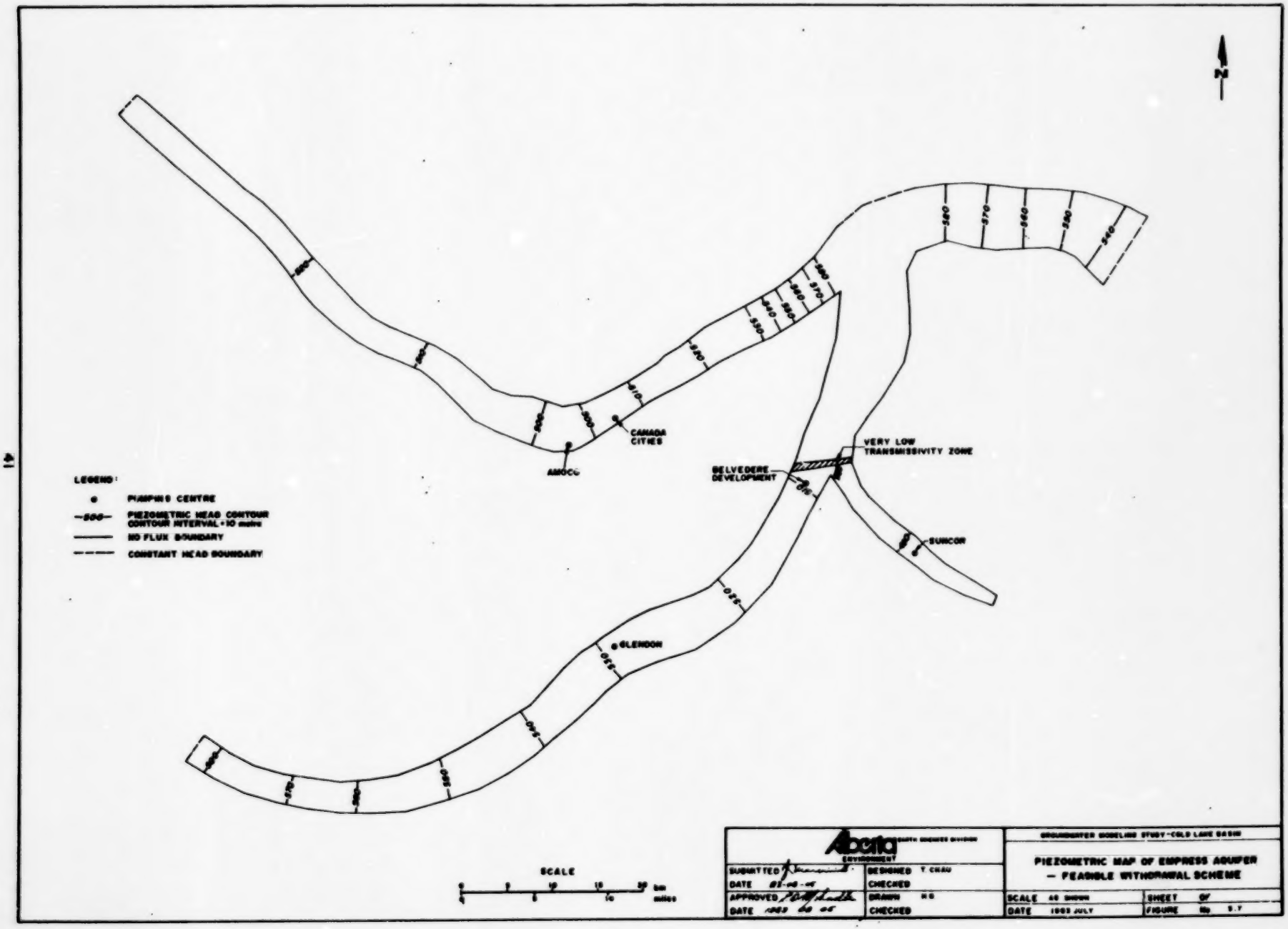
Scheme 5 - feasible



Alberta ENVIRONMENT EARTH SCIENCES DIVISION		GROUNDWATER MODELING STUDY-COLD LAKE BASIN
SUBMITTED	DESIGNED T. CHAU	DEMAND RESPONSE CURVES FOR THE EMPRESS AQUIFER
DATE 83-08-05	CHECKED	
APPROVED	DRAWN H.O.	SCALE —— / SHEET OF
DATE 1983 08 05	CHECKED	DATE 1983 JUNE / FIGURE No. 5.6

percentage of low demand. The plot shows a linear relationship between pumpage (percentage of demand) and response (hydraulic head) at all withdrawal locations, under a confined aquifer situation.

A feasible pumpage at each withdrawal center can be estimated from its linear response curve by choosing a demand that gives rise to the piezometric head above the top of the aquifer. To be conservative, the computed hydraulic head which was 10 metres above the top of the aquifer was chosen to give the pumpage for the feasible scheme. The pumpages, each expressed in terms of a percentage of the respective low demand, are 20% for Canada Cities, 15% for Amoco, 50% for Glendon, 40% for Suncor and 45% for Belvedere Development. For this scheme, the spatial head distribution is shown in figure 5.7. Comparing this figure with figure 5.2 which provides the computed steady state head distribution at the beginning of 1980, the regional flow direction differs along the Helina Channel. Groundwater withdrawals from Amoco and Canada Cities induce flow through the Helina constant head boundary. In general, a steeper hydraulic gradient exists along the Helina Channel. Detailed piezometric distributions around pumping centers for the two cases (steady state conditions resulting from the feasible withdrawal scheme and at the beginning of 1980) are presented, respectively, in figures 5.8 and 5.9. The deepening in the cones of depression is clearly illustrated for the higher withdrawal case.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LEGEND:
PIEZOMETRIC CENTRE
PIEZOMETRIC HEAD CONTOUR
CONTOUR INTERVAL = 10 metres
NO FLUX BOUNDARY
CONSTANT HEAD BOUNDARY
CANADA CITIES
AMOCO
BELVEDERE DEVELOPMENT
VERY LOW TRANSMISSIVITY ZONE
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GLENDON
SCALE
km
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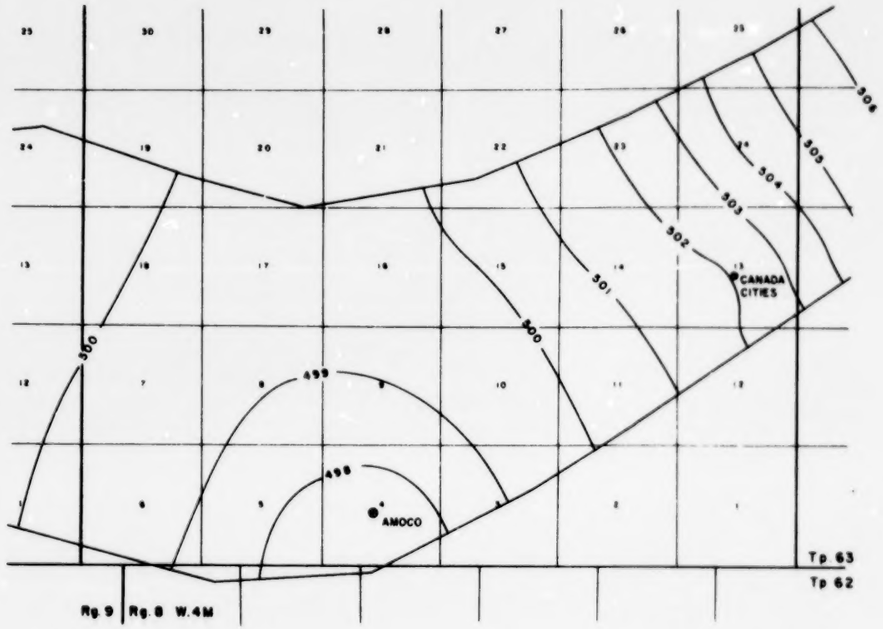
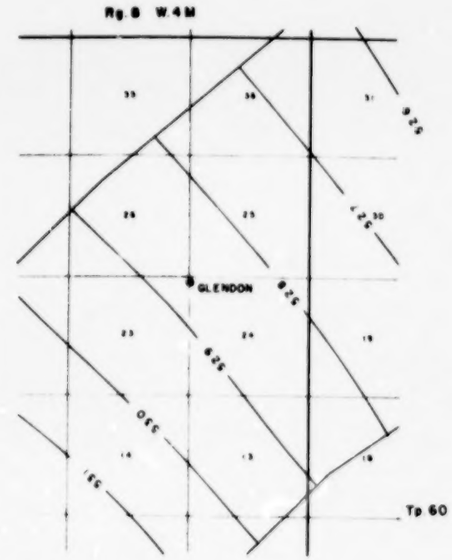
GROUNDWATER MODELLING STUDY - COLD LAKE BASIN
PIEZOMETRIC MAP OF EMPRESS AQUIFER
— FEASIBLE WITHDRAWAL SCHEME
SCALE AS SHOWN
DATE 1983 JULY
SHEET OF
FIGURE No. 5.7

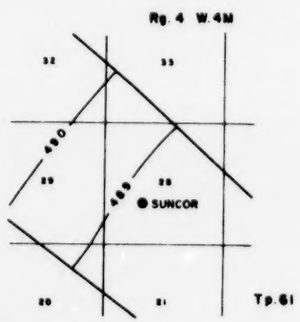


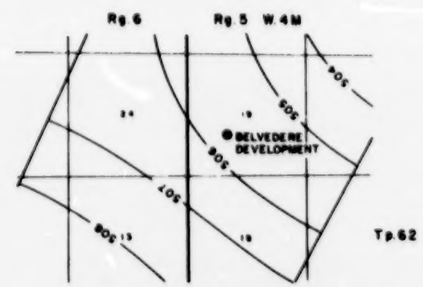


SCALE

0 1 2 3 4 km

0 1 2 3 miles



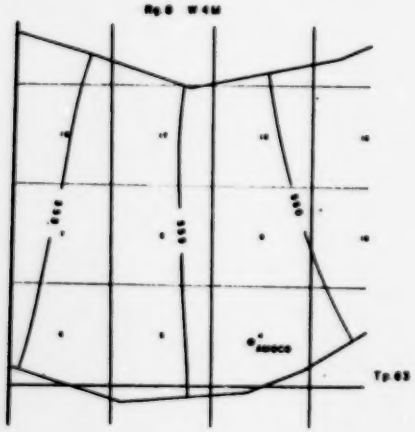


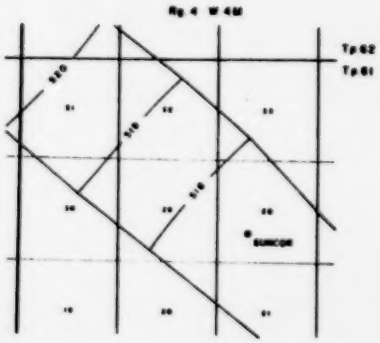
PIEZOMETRIC CONTOURS AROUND PUMPING CENTRES

LEGEND

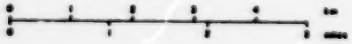
- ● PUMPING CENTRE
- 530 – PIEZOMETRIC CONTOUR CONTOUR INTERVAL = 1 metre
- AQUIFER BOUNDARY

Alberta Environment EARTH SCIENCES DIVISION		GROUNDWATER MODELING STUDY - COLD LAKE BASIN
SUBMITTED	DESIGNED T. CHAU	RESPONSE OF EMPRESS AQUIFER TO FEASIBLE WITHDRAWAL SCHEME
DATE 83-08-05	CHECKED	
APPROVED	DRAWN	SCALE AS SHOWN / SHEET OF
DATE 1983-08-05	CHECKED	DATE JULY 1983 / FIGURE No. 5.8





SCALE



PIEZOMETRIC CONTOURS AROUND PUMPING CENTRES

LEGEND:

- ⊙ PUMPING CENTRE
- —550— PIEZOMETRIC CONTOUR CONTOUR INTERVAL = 1 metre
- AQUIFER BOUNDARY

Alberta Environment EARTH SCIENCES DIVISION		GROUNDWATER MODELING STUDY COLD LAKE BASIN
SUBMITTED	DESIGNED T.CHAU	RESPONSE OF EMPRESS AQUIFER AT THE BEGINNING OF 1980
DATE	CHECKED	
APPROVED	DRAWN	SCALE AS SHOWN / SHEET OF
DATE	CHECKED	DATE JULY 1983 / FIGURE No 5.9

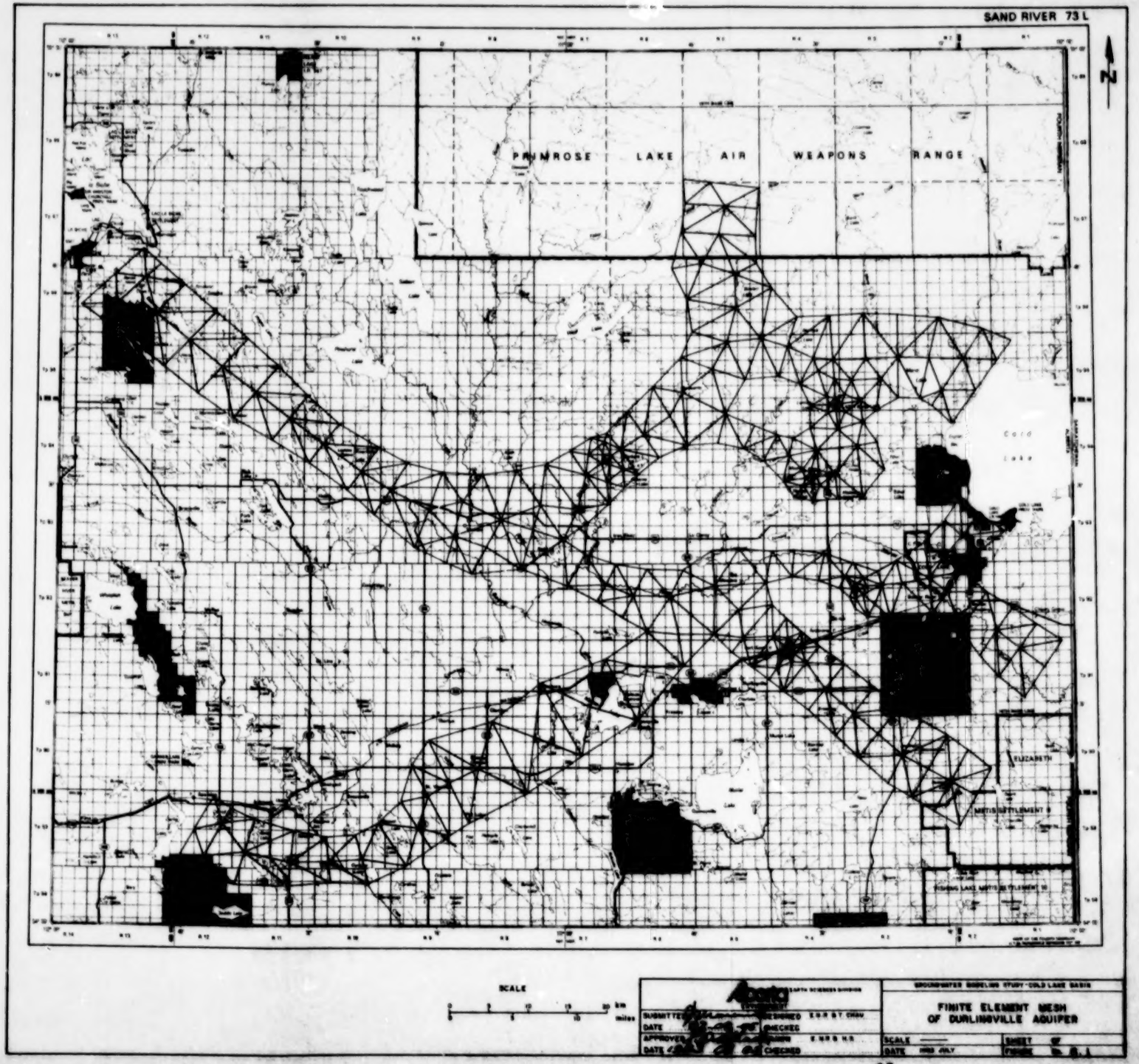
Chapter 6

APPLICATION OF MODEL TO DURLINGVILLE AQUIFER

6.1 Aquifer Description and Specification of Boundary Conditions

Figure 6.1 presents the finite element grid, representing the aquifer modelling domain. The grid consists of 444 elements and 312 nodes. The distance between the two closest nodes is about 800 metres. The potential groundwater users projected by the Planning Division include Husky Oil Operations Ltd., Municipal District of Bonnyville, Union Texas of Canada Ltd. and Mobil Oil Canada Ltd. As Mobil and Husky do not presently have any specific groundwater withdrawal locations, an artificial pumping node was assigned in each lease area. Glendon was also included as another groundwater user in the predictive analysis.

The Durlingville Aquifer has more inflow and outflow boundaries than the Empress Aquifer. The water level of Cold Lake provides the constant head boundary for the Helina Channel and the tributary linking Big Meadow Channel. Static water levels obtained at two wells provided the boundary conditions for the west end of the Beverly Channel and the east end of the Bronson Lake Channel. As for the rest of the constant head boundaries, reliable wells could not be identified. Some boundary heads were initially estimated by linearly extrapolating known piezometric heads within the aquifer domain. In other cases, the uncertain head (e.g., along Sinclair boundary) was initially estimated based on wells tapping a higher aquifer. BP Exploration Canada Ltd. and Alberta Environment had installed observation wells terminating at an aquifer above the Durlingville in the Sinclair Channel. Piezometric heads observed at these wells served as an initial estimate for the boundary head. The values were subsequently adjusted in order to simulate the observed heads in the modelling domain.


SAND RIVER 73 L
PRIMROSE LAKE AIR WEAPONS RANGE
Cold Lake
ELIZABETH
METIS SETTLEMENT 8
FISHING LAKE METIS SETTLEMENT 10
SCALE
km
miles
GROUNDWATER MODELING STUDY - COLD LAKE BASIN
FINITE ELEMENT MESH
OF DURLINGVILLE AQUIFER
SUBMITTED
DATE
APPROVED
DATE
DESIGNED
CHECKED
DRAWN
CHECKED
SCALE
DATE
SHEET
FIGURE

The linkage between the Helina and Beverly Channels is characterized by a zone of poorly sorted sand and till. Similiarly, a zone of low permeability constitutes a linkage between the Beverly and the Big Meadow Channels. A preliminary geological evaluation indicated that there is a hydraulic connection between the Beaver River and the Durlingville Aquifer. The river partially penetrates the channel and acts as an outflow boundary of the aquifer. The process of river-aquifer interaction was simulated in the model by applying a mixed type boundary condition to the nodes denoting the river. This condition relates the difference in heads between the river and the aquifer to the flux across the river-aquifer boundary. The aquifer outflow locations along the river were not known. That reach of the river crossing the Beverly Channel was assumed to be the aquifer outflow boundary in this study. River levels for the simulation period were required for model input because the quantity of aquifer outflow was governed by the difference in heads between the river and the aquifer. Since there was no gauging station along the river-aquifer interaction reach, the 1980 mean river level (496 m) determined at a gauging station (SE 15-62-2-W4) about 35 kilometres downstream was used for the simulation period. This assumption could introduce an error in computing the quantity of aquifer outflow to the river. At the time this study was performed, a crude estimate of the upstream river level based on the steady, uniform flow assumption could not be obtained because the gradient of the river bed for that reach was unknown.

6.2 Calibration of Model

The same calibration procedure for the Empress Aquifer was applied to the Durlingville Aquifer. The steady state hydraulic head distribution computed at the beginning of 1980 is presented in figure 6.2. Flow direction is in agreement with that described in section 4.2. The estimated recharge was 2.5×10^{-6} m/day. Table 6.1 shows the comparison between observed and computed heads at different locations in

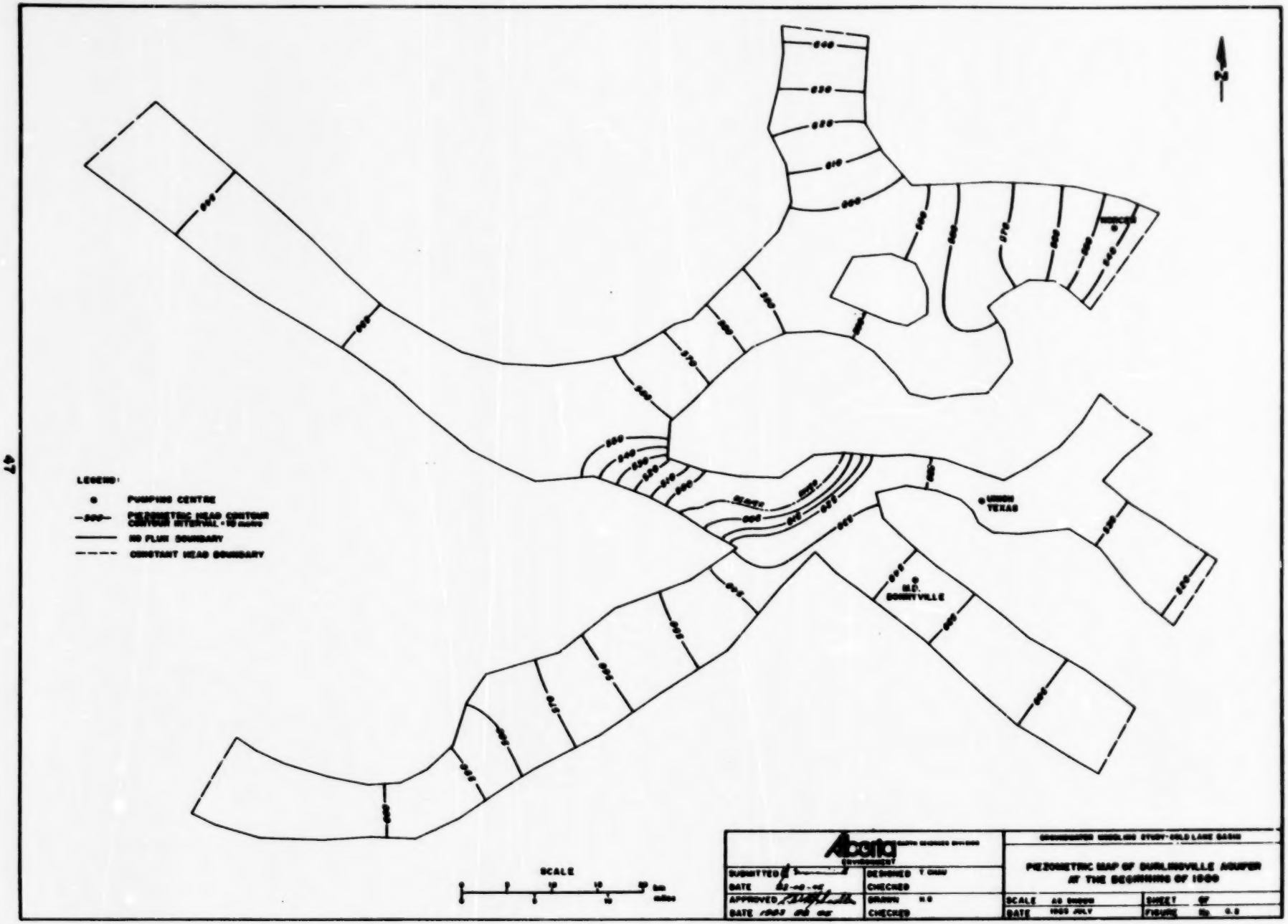

LEGEND:
PUMPING CENTRE
PIEZOMETRIC HEAD CONTOUR
NO FLUX BOUNDARY
CONSTANT HEAD BOUNDARY
UNION TEXAS
M.D. BONNYVILLE
SCALE
km
miles
Alberta
ENVIRONMENT
SUBMITTED
DATE
APPROVED
DATE
DESIGNED
CHECKED
DRAWN
CHECKED
PIEZOMETRIC MAP OF BURLINGVILLE AQUIFER
AT THE BEGINNING OF 1980
SCALE
DATE
SHEET
FIGURE

TABLE 6.1

Observed and Computed Steady State Heads in the Durlingville Aquifer

Well Location	Observed head (m)	Computed Head (m)
A.E. (Bonnyville)	530.4	530.7
A.E. (Bourque Lake)	591.9	587.0
A.E. (Iron River)	556.3	556.1
A.E. (Norcen)	546.3	546.1
A.E. (Rich Lake)	548.7	549.1
Esso	598.8	581.8
Glendon	565.0	564.8
M.D. Bonnyville	540.8	539.8
Union Texas	533.0	532.5

TABLE 6.2

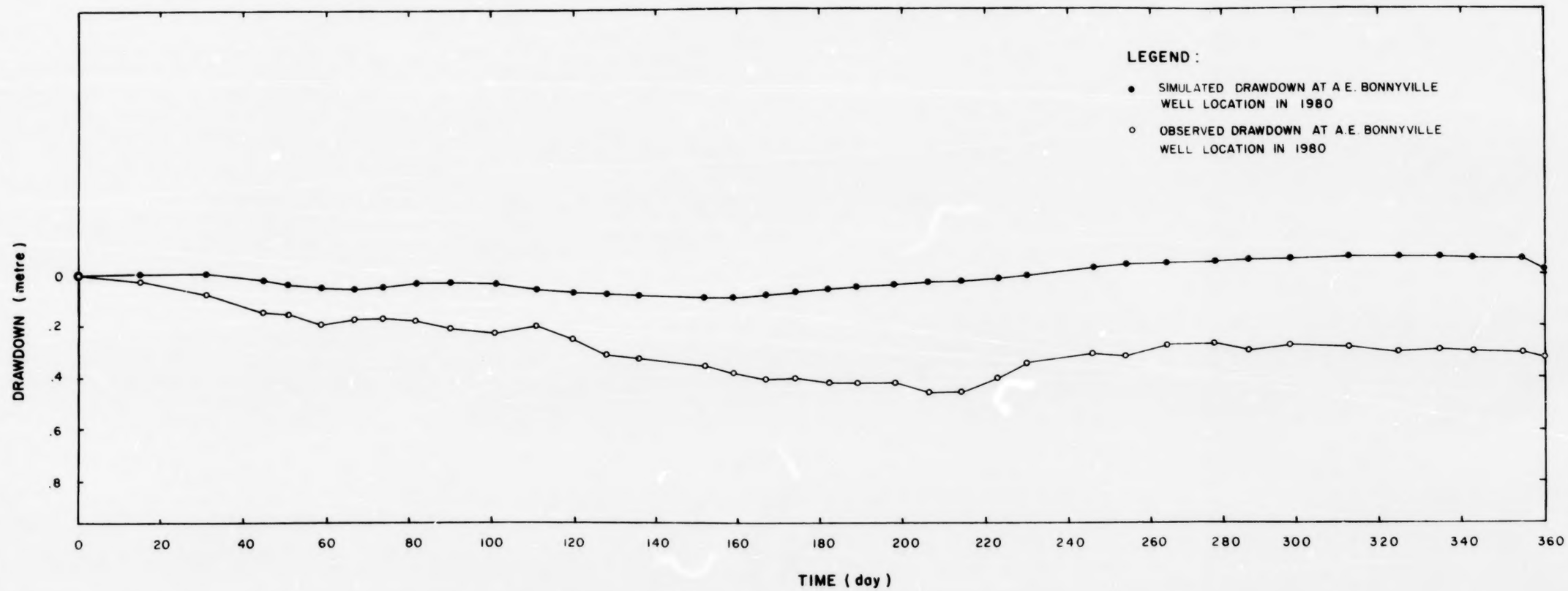
Projected Groundwater Demand for the Durlingville Aquifer

User	Low Demand		High Demand	
	(dam^3/yr)	(m^3/day)	(dam^3/yr)	(m^3/day)
Husky	160	438.4	1220	3342.8
Mobil	580	1589.2	2180	5973.2
Union Texas	180	493.2	730	2000.2
M.D. Bonnyville	100	274.0	240	657.6
Glendon	120	328.8	270	739.8

the Durlingville Aquifer. There is good agreement at most locations with the exception of the Alberta Environment well near Bourque Lake and the Esso well. This steady state hydraulic head distribution served as the initial condition for the transient simulation of the aquifer response during 1980. The computed and observed drawdowns at the A.E. (Bonnyville) well are shown in figure 6.3. Drawdowns computed with the model were less than those observed. The simplified pumping schedules for the Durlingville Aquifer, as given in figure 4.1, might not represent the actual pumpages for the simulation period. This could contribute a significant source of error in the transient simulation.

6.3 Predictive Capability

Table 6.2 summarizes high and low groundwater demands projected for the Durlingville Aquifer. The same allowable drawdown criterion used for the Empress was applied to the Durlingville. Model results indicated that the hydraulic head was above the aquifer top at all withdrawal locations for the low demand scheme. However, computed heads were below the top of the formation at Union Texas and Mobil locations for the high demand scheme. Further simulations were then carried out with various withdrawal schemes. Each scheme consists of different percentages of high demand for Mobil and Union Texas while maintaining other users at their respective high demands. Table 6.3 presents steady state aquifer response results for several groundwater withdrawal schemes. From schemes 1 to 4, hydraulic head and percentage of high demand for Mobil and Union Texas were plotted as shown in figure 6.4. A linear relationship exists between the two variables under a confined aquifer status. These demand response curves were used to decide on feasible withdrawals at the two pumping centers. The feasible withdrawal scheme consists of the following percentages of high demand: 55% for Mobil, 45% for Union Texas, 100% for Husky, 100% for M.D. Bonnyville and 100% for Glendon.



Alberta ENVIRONMENT — EARTH SCIENCES DIVISION		GROUNDWATER MODELING STUDY- COLD LAKE BASIN
SUBMITTED	DESIGNED T. CHAU	OBSERVED AND SIMULATED DRAWDOWNS - DURLINGVILLE AQUIFER
DATE 83-08-05	CHECKED	
APPROVED P.D. Wheatley	DRAWN	SCALE — / SHEET OF
DATE 1983 08 05	CHECKED	DATE JULY 1983 / FIGURE No. 6.3

TABLE 6.3

Steady State Responses To Several Pumping Schemes - Durlingville Aquifer

Pumping location	Aquifer top elevation (m)	Scheme 1		Scheme 2		Scheme 3		Scheme 4		Feasible scheme	
		Pumping rate (m^3/day)	Head (m)	Pumping rate (m^3/day)	Head (m)	Pumping rate (m^3/day)	Head (m)	Pumping rate (m^3/day)	Head (m)	Pumping rate (m^3/day)	Head (m)
Husky	509	3342.8	544.4	3342.8	547.0	3342.8	549.5	3342.8	552.0	3342.8	550.1
Mobil	515	5973.2	494.8	4778.6	508.5	3584.0	522.1	2389.3	535.7	3285.3	525.5
Union Texas	516	2000.2	513.0	1600.2	517.2	1200.1	521.3	800.1	525.4	900.1	524.4
M.D. Bonnyville	503	657.6	536.0	657.6	536.1	657.6	536.2	657.6	536.4	657.6	536.3
Glendon	533	739.8	552.5	739.8	552.5	739.8	552.6	739.8	552.6	739.8	552.6

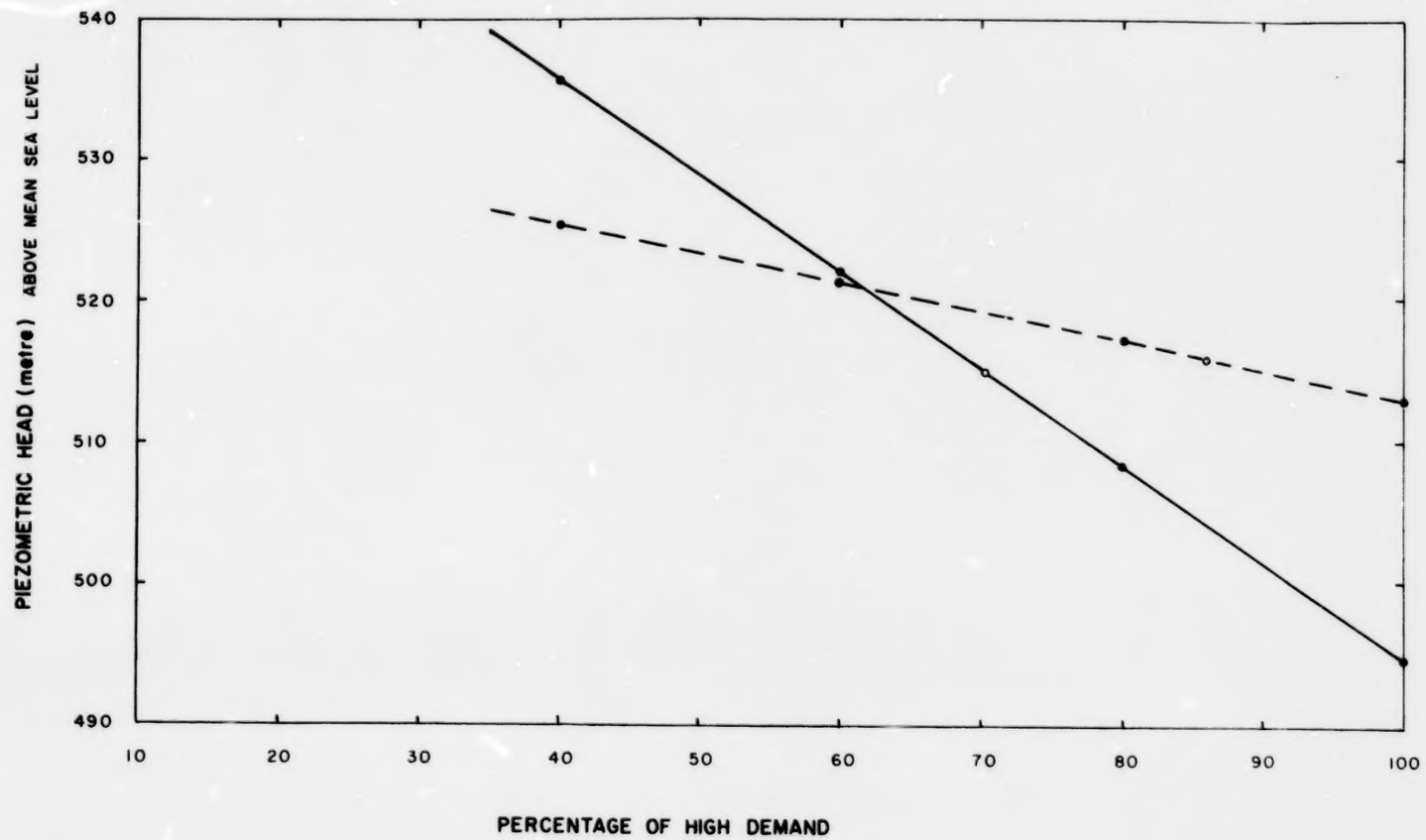
Scheme 1 - 100% of high demand

Scheme 2 - same as scheme 1, except 80% withdrawals at Union Texas and Mobil

Scheme 3 - same as scheme 1, except 60% withdrawals at Union Texas and Mobil

Scheme 4 - same as scheme 1, except 40% withdrawals at Union Texas and Mobil

Feasible Scheme - same as scheme 1, except 55% withdrawal at Mobil and 45% withdrawal at Union Texas



LEGEND:

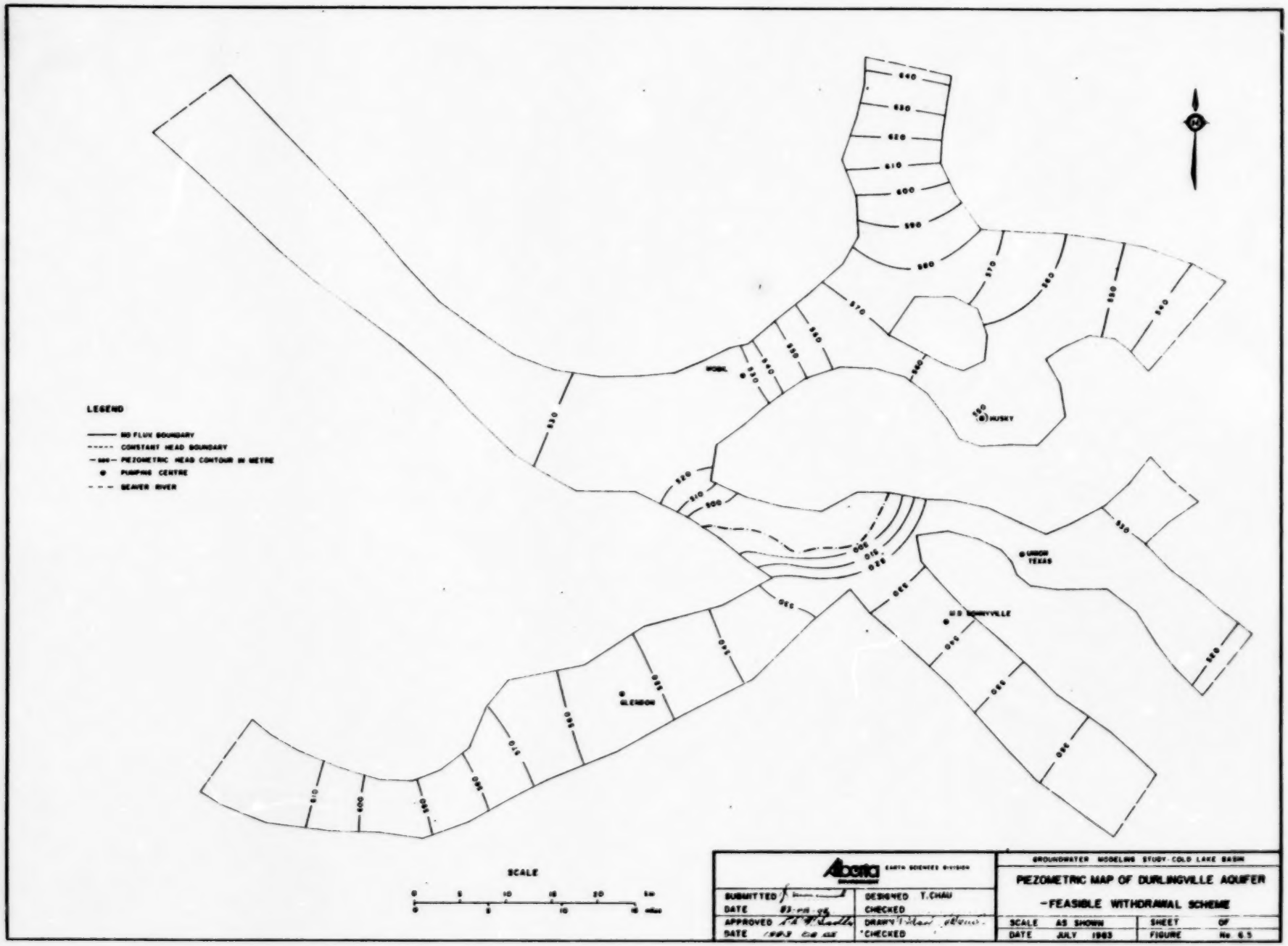
—•— MOBIL

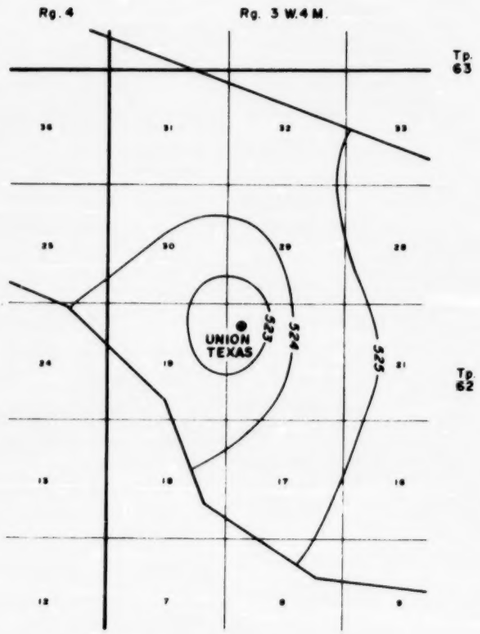
– –•– – UNION TEXAS

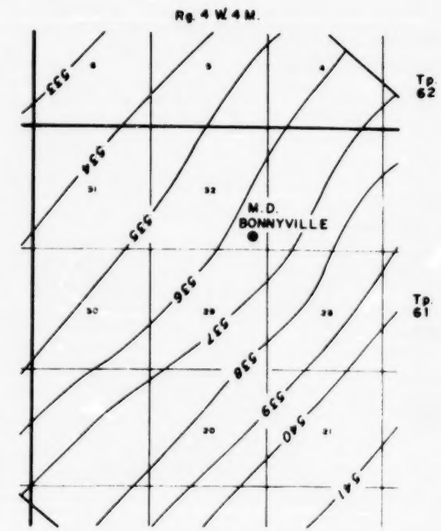
○ TOP OF AQUIFER AT THE WITHDRAWL LOCATION

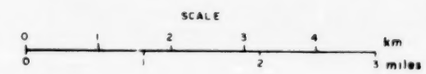
Alberta ENVIRONMENT — EARTH SCIENCES DIVISION		GROUNDWATER MODELING STUDY- COLD LAKE BASIN
SUBMITTED	DESIGNED T. CHAU	DEMAND RESPONSE CURVES FOR MOBIL AND UNION TEXAS
DATE 83-08-05	CHECKED	
APPROVED	DRAWN	SCALE — / SHEET OF
DATE 1983 08 05	CHECKED	DATE JULY 1983 / FIGURE No. 6.4

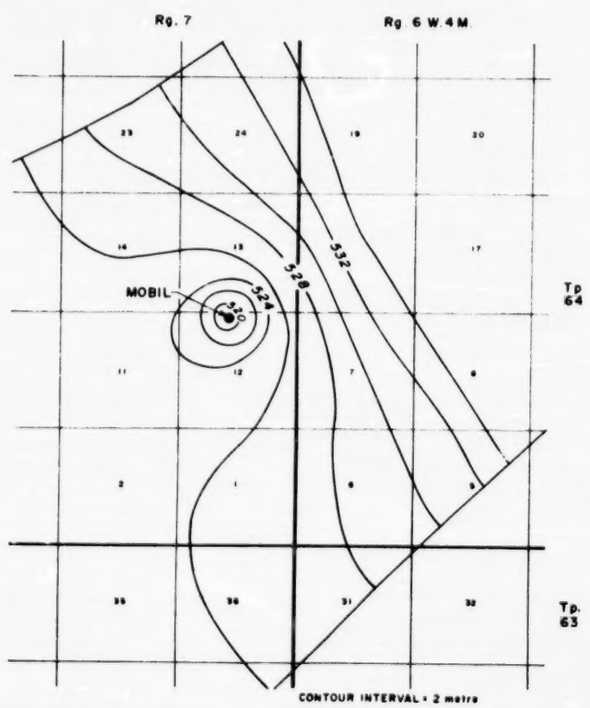
The steady state piezometric distribution of the aquifer under the feasible withdrawal scheme is presented in figure 6.5. The general flow pattern is similar to figure 6.2 which gives the steady state head distribution at the beginning of the simulation period. Due to higher withdrawal rates associated with the feasible scheme, a steep hydraulic gradient prevails near pumping centers and the regional flow pattern is also altered. This is clearly illustrated in figure 6.6 which shows detailed piezometric contours around pumping centers for the feasible groundwater withdrawal scheme. Comparing this figure with figure 6.7, showing hydraulic contours around pumping centers at the beginning of 1980, the change in hydraulic gradient is quite noticeable.

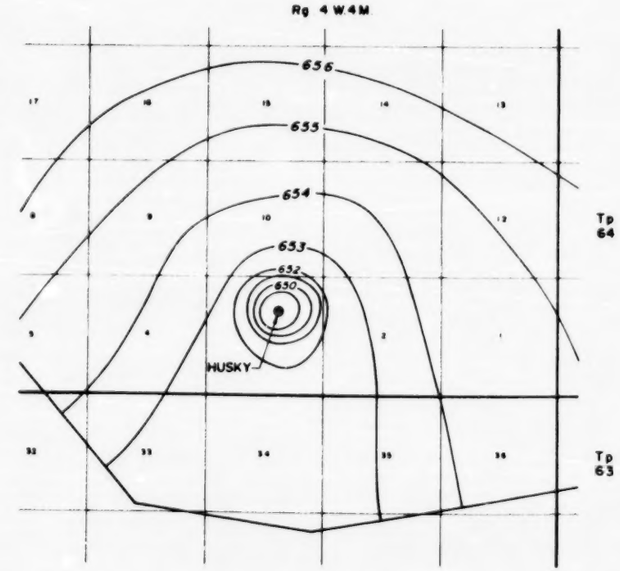

LEGEND
NO FLUX BOUNDARY
CONSTANT HEAD BOUNDARY
PIEZOMETRIC HEAD CONTOUR IN METRE
PUMPING CENTRE
BEAVER RIVER
MOBIL
HUSKY
UNION TEXAS
GLENDON
SCALE
Alberta
EARTH SCIENCES DIVISION
SUBMITTED
DATE
APPROVED
DATE
DESIGNED T. CHAU
CHECKED
DRAWN
CHECKED
GROUNDWATER MODELING STUDY COLD LAKE BASIN
PIEZOMETRIC MAP OF DURLINGVILLE AQUIFER
-FEASIBLE WITHDRAWAL SCHEME
SCALE AS SHOWN
SHEET OF
DATE JULY 1983
FIGURE No. 6.5









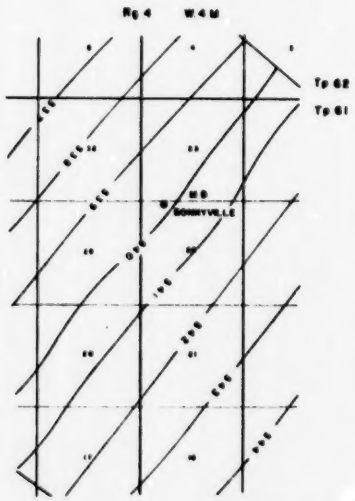


PIEZOMETRIC CONTOURS AROUND PUMPING CENTRES

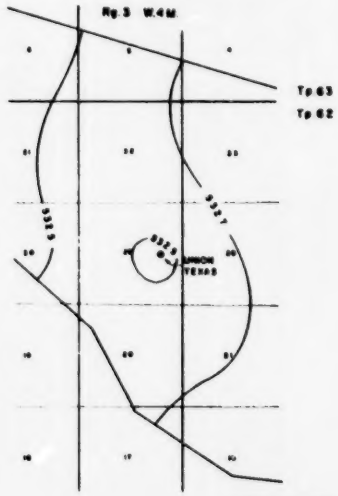
LEGEND

- ● PUMPING CENTRE
- —655— PIEZOMETRIC CONTOUR CONTOUR INTERVAL = 1 metre UNLESS OTHERWISE STATED
- AQUIFER BOUNDARY

Alberta ENVIRONMENT EARTH SCIENCES DIVISION		GROUNDWATER MODELING STUDY-COLD LAKE BASIN	
SUBMITTED	DESIGNED T. CHAU	RESPONSE OF DURLINGVILLE AQUIFER TO FEASIBLE WITHDRAWAL SCHEME	
DATE 83-08-05	CHECKED		
APPROVED	DRAWN H.O.	SCALE AS SHOWN	SHEET OF
DATE 1983 08 05	CHECKED	DATE 1983 JULY	FIGURE No. 6.6



CONTOUR INTERVAL = 1.0 metre



CONTOUR INTERVAL = 0.2 metre

PIEZOMETRIC CONTOURS AROUND PUMPING CENTRES

LEGEND:

- PUMPING CENTRE
- PIEZOMETRIC CONTOUR
- AQUIFER BOUNDARY

SCALE

0 1 2 3 4 km

0 1 2 3 miles

Alberta Environment — Earth Sciences Division		GROUNDWATER MODELLING STUDY - COLD LAKE BASIN	
SUBMITTED	DESIGNED T CHAU	RESPONSE OF DURLINGVILLE AQUIFER AT THE BEGINNING OF 1980	
DATE	CHECKED		
APPROVED	DRAWN	SCALE AS SHOWN	SHEET OF
DATE 1983 06 07	CHECKED	DATE JULY 1983	FIGURE No. 6.7

Chapter 7

CONCLUSIONS

Conclusions reached during various stages of this modelling study are summarized below:

(1) The data collection and interpretation phase indicated that hydrogeologic information was scarce compared to the relatively large amount of geological data. The observation well network in each formation was inadequate to define the regional flow pattern. The same difficulty was encountered in determining the spatial distribution of aquifer properties.

(2) The model was designed to simulate (approximately) the overall dynamic response of the aquifer system and was not intended to produce a particle by particle comparison for the complex hydrogeologic system. However, the magnitude of discrepancies between observed and simulated responses at certain locations in the basin indicate definite areas where additional data should be obtained to improve the understanding of the aquifer system. For example, the large difference in heads at Amoco and Canada Cities wells suggested more data is needed to identify a possible source of outflow from the Helina Channel. This data requirement was further supported by the sensitivity study, showing that it was not possible to reduce the large discrepancy simply by tuning existing parameters and boundary conditions.

(3) Based on the existing observation well network and numerous simulations, inferences are drawn on the general flow pattern in the Empress Aquifer. Flow from the northern Sinclair Channel is divided at the junction of three channels (Sinclair, Beverly and Helina). The main component flows east through the Helina Channel into Cold Lake, while the other component flows west along the

Helina Channel until it encounters the outflow boundary discussed previously. This boundary further acts as a discharge zone for flow coming from the west of the Helina Channel. That component flowing south along the Beverly Channel terminates at the geologic discontinuity zone (north of the Belvedere Development). On the south side of this discontinuity, flow along the Beverly Channel is from the west to east towards the Bronson Lake Channel.

(4) The parameter sensitivity study with the model illustrated the relative importance of different parameters in affecting the aquifer response. Results showed that the hydraulic head was insensitive to transmissivity changes. It was affected much more by the change in the storage coefficient. If interest is focused on the steady state behaviour of the aquifer system, as in the prediction phase, then errors in estimating aquifer properties would only slightly affect the accuracy of the output. In that case, rather than going into a costly pumping test field program for aquifer properties identification, efforts should be directed instead towards better estimation of aquifer stresses (pumpage and recharge) and specification of reliable boundary head conditions.

(5) In the predictive phase, the Durlingville Formation was shown to have higher potential for groundwater development than the Empress Formation. The feasible groundwater withdrawal scheme for water users in each aquifer was summarized in tables 5.5 and 6.3. This assessment was made based on our present understanding of the aquifer system.

(6) The magnitude of recharge can be an important factor in deciding the groundwater allocation potential of the aquifer. The recharge, determined during the calibration phase of the simulation, can be quite sensitive to the change in boundary conditions. If the discharge zone in the Helina Channel, within the Empress Formation,

does exists, the estimated recharge for the Empress Aquifer may increase accordingly. By the same token, the estimated recharge for the Durlingville Aquifer could be excessive because the computed outflow into the Beaver River from the aquifer was on the high side. The excessive outflow resulted primarily from a lack of information on the locations of river-aquifer interaction and the river level. This indicates the necessity of specifying such reasonable boundary conditions.

(7) The numerical model is an useful tool to evaluate long-term safe yield of an aquifer because of its capability to include various types of boundary conditions. Comparison of safe yield results obtained by the numerical and analytical means should be made on the basis of the assumptions and criteria used to derive them.

Chapter 8

RECOMMENDATIONS

Based on the results of this study, the following recommendations are presented:

(1) A field program is essential to identify a possible discharge location for the Empress Aquifer along that reach (63-8-W4) of the Helina Channel. Detailed geologic interpretation, supplemented with more data from a field program, is needed to identify locations of hydraulic connections between the Beaver River and the Durlingville Aquifer. This together with a river gauging station for water level measurement would provide a better means for specifying proper boundary conditions in the model to simulate the process of river-aquifer interaction.

(2) Lack of reliable data to specify piezometric heads along inflow and outflow boundaries of the modelling domain was experienced. To identify flow direction in the Sinclair Channel, observation wells should be installed in the Empress and Durlingville Formations. Observation wells to define the piezometric boundary head in the Big Meadow and Bronson Lake Channels are essential to provide a quantitative assessment of regional flow in the Durlingville Formation. These wells would further serve to monitor the hydrologic impact on the aquifer system resulting from future groundwater mining.

(3) In this study, the constraint in maintaining the steady state piezometric head above the top of the formation was used to arrive at feasible pumping schemes. Using a linear programming formulation, it is conceptually possible to introduce other constraints (economic or physical) and objective functions into the flow model to achieve optimal aquifer management. Future modelling effort should combine the finite element and linear programming methods to study the groundwater allocation in the basin.

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APPENDIX A

MATHEMATICAL FORMULATION OF THE NUMERICAL MODEL

A two dimensional finite element aquifer flow model (AQUIFEM), developed by Townley and Wilson (1980), was used for this study. The model is based on the Galerkin formulation and uses linear interpolation functions with triangular elements. The finite element formulation of the governing equation and the solution technique used to solve the system of matrix equations are presented in this Appendix.

A.1 Governing Equation and Boundary Conditions

The numerical model used for this investigation solves the following differential equation, describing two-dimensional, nonsteady flow in a non-homogenous anisotropic aquifer:

$$S \frac{\partial h}{\partial t} = \frac{\partial}{\partial X_i} \left(T_{ij} \frac{\partial h}{\partial X_j} \right) + Q + \frac{K'}{B'} (h_a - h) \qquad i,j = 1,2 \quad (A.1)$$

where

- S is the aquifer storage coefficient,
- h is the hydraulic head (L),
- T_{ij} is the transmissivity tensor (L^2T^{-1}),
- Q is the vertical flux into the aquifer from point sources or sinks (LT^{-1}),
- K' is the vertical permeability of the semi-pervious confining layer (LT^{-1}),
- B' is the thickness of the confining layer (L),
- h_a is the hydraulic head in an adjacent aquifer separated from the main aquifer by the semi-pervious confining layer (L).

Equation (A.1) is derived under several main assumptions. Darcy's Law is considered to be valid. The assumption of essentially horizontal

flow in the aquifer is applicable. Vertical flow exists only in the semi-previous layer overlying the aquifer and the effect of time dependent storage in this layer is not considered. Aligning the x and y axes along the principal directions of the transmissivity tensor, off diagonal terms of the transmissivity tensor are zero ($T_{12} = T_{21} = 0$, $T_{11} = T_{xx}$, $T_{22} = T_{yy}$).

Equation A.1 is to be solved in the aquifer modelling domain subject to the following three types of boundary conditions and an initial condition:

$$h = h_1 \ (x,y,t) \qquad \text{on } \Gamma_1 \qquad (A.2)$$

$$-\left(T_{xx} \frac{\partial h}{\partial x} n_x + T_{yy} \frac{\partial h}{\partial y} n_y\right) = Q_s \ (x,y,t) \qquad \text{on } \Gamma_2 \qquad (A.3)$$

$$-\left(T_{xx} \frac{\partial h}{\partial x} n_x + T_{yy} \frac{\partial h}{\partial y} n_y\right) = \frac{K''W''}{B''} (h_3 - h) \qquad \text{on } \Gamma_3 \qquad (A.4)$$

$$h = h_o \ (x,y,t_o) \qquad \text{in } \Omega \qquad (A.5)$$

where

Γ_1, Γ_2, Γ_3 are the boundary segments of the aquifer domain Ω, on each of which the essential, natural and mixed boundary conditions are respectively specified,

h_1 is the prescribed head on Γ_1 (L),

Q_s is the prescribed lateral flux on Γ_2 (L^2T^{-1}),

n_x, n_y are the x and y components of the unit inward-pointing normal vector $\underline{n}$ on Γ_2 or Γ_3,

T_{xx}, T_{yy} are transmissivities in x and y directions on Γ_2 and Γ_3 (L^2T^{-1}),

K'' is the equivalent hydraulic conductivity of the leaky layer on Γ_3 (LT^{-1}),

B'' is the thickness of the leaky layer on Γ_3 (L),

W'' is width perpendicular to the inflow on Γ_3 (L),

h_o is the prescribed head in the aquifer domain Ω at time t_o (L).

A.2 The Galerkin Finite Element Formulation

The governing equation A.1 can be written in the form

$$L(h) - f = 0 \tag{A.6}$$

L(h) is a linear differential operator on the piezometric head h in the aquifer domain Ω and f is the function representing known sources, sinks and leakage. This gives

$$L(h) = S \frac{\partial h}{\partial t} - \frac{\partial}{\partial x} (T_{xx} \frac{\partial h}{\partial x}) - \frac{\partial}{\partial y} (T_{yy} \frac{\partial h}{\partial y}) + \frac{K'}{B'} h \tag{A.7}$$

$$f = Q + \frac{K'}{B'} h_a \tag{A.8}$$

The aquifer domain is discretized into triangular elements with nodal points. By introducing a set of approximating functions of the form

$$h \cong \hat{h} = \sum_{j=1}^{NEQ} N_j(x,y) h_j(t) + \sum_{j=NEQ+1}^{NUMNP} N_j(x,y) g_j(t) \tag{A.9}$$

where

$N_j(x,y)$ is the jth shape function with value 1 at node j and value 0 at all other nodes, $1 \leq j \leq$ NUMNP,

$h_j(t)$ is the approximate value of h at node j at time t, $1 \leq j \leq$ NEQ,

$g_j(t)$ is the specified head at node j on Γ_1, at time t, $(NEQ+1) \leq j \leq$ NUMNP,

NUMNP is the number of nodal points,

NEQ is the number of nodal points at which head is unknown.

Substitution of this approximating function $\hat{h}$ into equation A.6 does not satisfy exactly the equation. Instead, it gives rise to an error or residual ε which is given as

$$L(\hat{h}) - f = \varepsilon \tag{A.10}$$

Introducing weighting functions $W_i(x,y)$, i=1, ..., NEQ, which equal to zero on the prescribed head boundary Γ_1, the method of weighted residuals (Finlayson, 1972) requires

$$\int_\Omega (L(\hat{h}) - f)\, W_i \, d\Omega = 0 \tag{A.11}$$

This is equivalent to forcing the error of the approximate differential equation A.10 to zero in an average sense. There are a number of ways to choose the weighting functions. In the Galerkin method, the shape functions $N_i(x,y)$, i=1, ..., NEQ, are selected as the weighting functions. The Galerkin method of approximation to the governing equation A.1 generates the following sets of integral equations:

$$\int_\Omega (L(\hat{h}) - f)\, N_i \, d\Omega = 0 \tag{A.12}$$

Equations A.7 and A.8 are substituted into equation A.12. The Green's theorem is then used to reduce the second order derivatives in $L(\hat{h})$ to first order and to introduce the natural boundary condition. Replacing $\hat{h}$ in equation A.12 with the approximating function of equation A.9, the following system of simultaneous ordinary differential equations in time for unknown nodal hydraulic heads are derived by Wilson, et al. (1979):

$$\underline{\underline{M}}\dot{\underline{h}} + \underline{\underline{K}}\underline{h} = \underline{f} - (\underline{\underline{M}}^* \dot{\underline{q}} + \underline{\underline{K}}^* \underline{q}) = \underline{f}^* \tag{A.13}$$

where

$\underline{h} = \{h_j\}$ j=1, ..., NEQ, is a vector of unknown nodal values,

$\dot{\underline{h}} = \frac{d}{dt}(\underline{h})$

$\underline{g} = \{g_j\}$ j=(NEQ+1), ..., NUMNP, is a vector of specified nodal values of head on Γ_1,

$\dot{\underline{g}} = \frac{d}{dt}(\underline{g})$

$\underline{\underline{M}} = \{m_{ij}\}$ i,j=1, ..., NEQ, is the capacity or storage matrix representing storage effects,

$\underline{\underline{M}}^* = \{m_{ij}\}$ i=1, ..., NEQ and j=(NEQ+1), ..., NUMNP,

$\underline{\underline{K}} = \{k_{ij}\}$ i,j=1, ..., NEQ, is the conductivity or stiffness matrix representing transmissive effects and some effects of leakage and mixed type boundaries,

$\underline{\underline{K}}^* = \{k_{ij}\}$ i=1, ..., NEQ and j=(NEQ+1), ..., NUMNP,

$\underline{f} = \{f_i\}$ i=1, ..., NEQ, is the flux vector representing the effects of flux boundaries, sources/sinks, and part of the contribution of leakage and mixed type boundaries,

$\underline{f}^* = \{f_i^*\}$ i=1, ..., NEQ is the right-hand side vector in Eq. A.13 which includes the flux vector $\underline{f}$ and the effect of prescribed head boundaries.

The individual terms of the matrices $\underline{\underline{M}}$ and $\underline{\underline{K}}$ and vector $\underline{f}$ are

$$m_{ij} = \int_\Omega S N_i N_j d\Omega \tag{A.13a}$$

$$K_{ij} = \int_\Omega \left(T_{xx} \frac{\partial N_i}{\partial x}\frac{\partial N_j}{\partial x} + T_{yy}\frac{\partial N_i}{\partial y}\frac{\partial N_j}{\partial y} + \frac{K'}{B'} N_i N_j\right) d\Omega + \int_{\Gamma_3} \frac{K''W''}{B''} N_i N_j d\Gamma_3 \tag{A.13b}$$

$$f_i = \int_{\Gamma_2} N_i Q_s d\Gamma_2 + \int_{\Gamma_3} N_i \frac{K''W''}{B''} h_3 d\Gamma_3 + \int_\Omega N_i \left(Q + \frac{K'}{B'} h_a\right) d\Omega \tag{A.13c}$$

The single and double underlines are used to present a vector and a matrix respectively.

A.3 Solution Technique

In this study, both steady state and transient solutions of equation A.13 were sought for a confined aquifer. Under steady state condition ($\frac{\partial h}{\partial t} = 0$), a boundary valued problem arises and equation A.13 is reduced to

$$\underline{\underline{K}}\ \underline{h} = \underline{f}^* \tag{A.14}$$

which is a system of simultaneous linear algebraic equations. The Crout's algorithm, taking advantage of the banded structure of $\underline{\underline{K}}$, is used to solve the unknown heads.

Under unsteady condition, an initial valued problem results. A transient, linear (transmissivity is independent of head for a confined aquifer) solution of equation A.13 is therefore required. Using a finite difference temporal scheme to approximate $\dot{\underline{h}}$, the following set of algebraic equations that are solved at each time step are derived by Wilson, et al. (1979).

$$\left(\frac{1}{\alpha\Delta t}\underline{\underline{M}} + \underline{\underline{K}}\right)\underline{h}_{n+1} = \underline{f}_{n+1} - \underline{\underline{M}}^*\ \dot{\underline{g}}_{n+1} - \underline{\underline{K}}^*\ \underline{g}_{n+1} + \frac{1}{\alpha\Delta t}\underline{\underline{M}}\ \tilde{\underline{h}}_{n+1} \tag{A.15}$$

The subscript n+1 denotes the n+1 th time step. α is a weighting coefficient which determines the stability and accuracy of the solution. The algorithm described by equation A.15 is unconditionally stable for $0.5 \leq \alpha \leq 1$. $\tilde{\underline{h}}_{n+1}$, a predictor of the vector $\underline{h}_{n+1}$, is

$$\tilde{\underline{h}}_{n+1} = \underline{h}_n + (1-\alpha)\ \Delta t\ \underline{V}_n \tag{A.16}$$

and $\underline{V}_n$ is defined as

$$\underline{V}_n = \frac{\underline{h}_n - \tilde{\underline{h}}_n}{\alpha\Delta t} \tag{A.17}$$

Compution of $\underline{h}$ in time proceeds in the following manner. $\underline{h}_o$ is given as an initial condition at time t_o. $\underline{V}_o$ is obtained from equation A.13 as $\underline{V}_o = M^{-1} (\underline{f}_o - K \underline{h}_o)$. This completes the initialization step for computing $\underline{V}_o$. Since $\underline{h}_o$, $\underline{V}_o$ are known, equation A.16 is used to compute $\underline{\tilde{h}}_1$ which is then substituted in equation A.15 to obtain $\underline{h}_1$. $\underline{V}_1$ is calculated next from equation A.17. The same computation procedure for $\underline{h}$ applies to the rest of the time steps.

The steady and transient responses of the aquifer system were obtained with the model using the numerical technique outlined in this Appendix.

APPENDIX B

FEASIBILITY OF 3-DIMENSIONAL MODELLING

The geological description of the study area, presented in Chapter 2, suggests that a multilayered or a three dimensional (3-D) flow model provides the best means of representing complicated multilayered, surficial aquifer systems. Although much progress and continuing research has been made in the theoretical development of 3-D or multilayered models, many of these models have only been verified with analytical solutions and small hypothetical systems (Javandel and Witherspoon, 1968; Freeze, 1971). Very few have been applied sufficiently to real basins under actual field conditions. The reason is that, with most 3-D simulations of real basins, there is often insufficient hydrogeologic information available for model input and calibration.

Gupta and Tanji (1976) applied a 3-D finite element flow model using isoparametric elements to the analysis of flow through multiaquifers in Sutter Basin, California. In that study, the model was directed towards steady state application. Hence no consideration was given to include a movable water table boundary in the formulation, a condition necessary for the simulation of the dynamic response in a natural basin. Frind and Verge (1978) applied a transient, saturated-unsaturated finite element model to study the 3-D flow in a hypothetical system and a real basin. This transient model requires the specification of the groundwater surface as the atmospheric boundary condition. It is difficult to obtain enough accurate data for a real basin to provide this top boundary condition for model input. Another aspect that needs to be considered for a 3-D basin simulation is the computing cost which is much higher than the comparable 2-D simulation. The high computing cost as a limiting factor in 3-D modelling was pointed out by Appel (1975) in his review on groundwater models. Lastly, the

manpower involved in data interpretation, grid design and preparation of input data is another economic factor to be considered. The practicality of 3-D aquifer modelling for the study area was evaluated prior to the study. Review of the presently available hydrogeologic data showed that the data base was inadequate to define the 3-D system and to calibrate the model. A costly aquifer identification field program will be required to serve this purpose. Within the economic and time constraints imposed on this study, it was decided to proceed with 2-D modelling of the Empress and Durlingville Aquifers, treating the aquifers independently of each other. A two dimensional finite element aquifer flow model was used to simulate horizontal groundwater flow in each aquifer under the assumption that vertical flow was negligible compared to the horizontal component.

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